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PHOTOTHERAPY FOR SAD: A META-ANALYTIC REVIEW

BY

TATIA M. C. LEE ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN
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Tatia M. C. Lee
545 Ferris Street
Coquitlam
British Columbia
Canada V3J 7L3

Date: August 10, 95

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled PHOTOTHERAPY FOR SAD: A META-ANALYTIC REVIEW submitted by Tatia M. C. Lee in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Educational Psychology.

Dr. H.L. Janzen (Supervisor)

C.A. Blashko, MD
Dr. C.A. Blashko

Peter Calder
Dr. P. Calder

Dr. J.G. Paterson

Dr. L.L. Stewin

Dr. J.F. Wolfaardt

Dr. W. Borgen

Date: May 29/95

Abstract

Phototherapy for seasonal affective disorder (SAD) has been actively studied lately. Many contentious issues about the optimum parameters of light used in treating SAD have been raised. Identifying the common issues underlying these data of phototherapy studies will enhance understanding of the pathophysiology of SAD as well as delineate optimum treatment guidelines of phototherapy for SAD. Using meta-analysis methodology to pool and re-examine the available data in the field, these common issues can be identified.

Forty published and unpublished studies of phototherapy for SAD conducted in Europe, Asia, North America, and Australia were included in this meta-analysis. Dose of light and timing of phototherapy administration were examined.

The present findings support the dose-response relationship of phototherapy for the alleviation of the typical symptoms of SAD, i.e. the therapeutic effect varied positively with the intensity of light used. Furthermore, phototherapy administered in both morning and evening is more effective than a single pulse of light delivered at any time of day. With respect to the pathophysiology of SAD, the pattern of the findings tends to support the photon-count hypothesis of SAD when light used is of medium intensity (1700 lux to 3500 lux).

Different parameters of phototherapy tend to act on the typical and the atypical symptoms of SAD differently. This

suggests that measures of both the typical and atypical depressive symptoms should be employed for phototherapy studies for SAD.

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Table of Contents

PAGE

I. **INTRODUCTION**..........1

II. **SEASONAL AFFECTIVE DISORDER - AN OVERVIEW**..........5
  Clinical Features
  Epidemiology
  Diagnostic Criteria
  Measuring Instruments for SAD
  Pathophysiology of SAD
  SAD - A Distinct Clinical Entity

III. **PHOTOTHERAPY FOR SAD**..........37
  Phototherapy for SAD
  Light Source
  Dosing Dimensions of Phototherapy
  Side Effects of Phototherapy

IV. **META-ANALYSIS - INTEGRATION OF RESEARCH FINDINGS**....51

V. **METHOD**..........55
  Stage I - Problem Formulation
  Stage II - Data Collection: Searching the Literature
  Stage III - Data Evaluation and Coding
  Stage IV - Analysis

VI. **RESULTS**..........75
  Description of the Sample
  Validity
  Reliability
  Hypothesis Testing

Page

VII. DISCUSSION..105
SAD Population Characteristics
Efficacy of Phototherapy
Other Plausible Pathophysiological Mechanisms of SAD
Heterogeneity of the SAD Population
Limitations and Delimitation

VIII.CONCLUSION..132

REFERENCES...134

APPENDIX 1...153

APPENDIX 2...156

APPENDIX 3...157

APPENDIX 4...165

APPENDIX 5...169

APPENDIX 6...172

List of Tables

PAGE

Table 6.1: Country of Origin of Studies.................78

Table 6.2: City of Origin of the Studies................79

Table 6.3: Agreement of raters' rating on History.....................................87

Table 6.4: Agreement of raters' rating on Instrumentation.............................88

Table 6.5: Agreement of raters' rating on Statistical Regression......................88

Table 6.6: Agreement of raters' rating on Maturation..................................89

Table 6.7: Agreement of raters' rating on Attrition...................................89

Table 6.8: Agreement of raters' rating on Selection...................................90

Table 6.9: Agreement of raters' rating on Testing.....................................90

Table 6.10: Meanings of notations.......................91

Table 6.11: Overall effect of phototherapy..............94

Table 6.12: Effect of morning phototherapy of different intensities measured by the HDRS.................................96

Table 6.13: Effect of morning phototherapy of different intensities measured by the AS...................................97

Table 6.14: Effect of morning-evening phototherapy of different intensities measured by the HDRS.................................98

Table 6.15: Effect of medium light phototherapy administered at different times of day measured by the HDRS..................100

Table 6.16: Effect of medium light phototherapy administered at different times of day measured by the AS....................101

PAGE

Table 6.17: Effect of dim light phototherapy administered at different times of day measured by the HDRS....................103

Table 7.1: Treatment effectiveness of morning phototherapy of varying intensities measured by the HDRS........................110

Table 7.2: Treatment effectiveness of morning phototherapy of varying intensities measured by the AS..........................111

Table 7.3: Treatment effectiveness of morning-evening phototherapy of varying intensities measured by the HDRS........................112

Table 7.4: Treatment effectiveness of medium light intensity light therapy administered at different times as measured by the HDRS.....117

Table 7.5: Treatment effectiveness of medium light intensity light therapy administered at different times as measured by the AS.......117

Table 7.6: Treatment effectiveness of dim light intensity light therapy administered at different times as measured by the HDRS...117

Table A6.1: Effect of light of different wavelengths for treatment of SAD measured by the HDRS........................173

Table A6.2: Results of the contrast of ANOVA (Morning light subgroup)....................174

Table A6.3: Results of the contrast of ANOVA (Evening light subgroup)....................175

Table A6.4: Results of the contrast of ANOVA (Morning-Evening light subgroup)............175

Table A6.5: Effect of light of different wavelengths for treatment of SAD measured by the AS..........................176

Table A6.6: Treatment effectiveness of different spectra of light measured by the HDRS.......178

Table A6.7: Treatment effectiveness of different spectra of light measured by the AS.........178

List of Figures

PAGE

Figure 6.1: Morning light of medium intensity (HDRS)....................................84

Figure 6.2: Evening light of medium intensity (HDRS)....................................84

Figure 6.3: Morning-Evening light of medium intensity (HDRS)....................................85

Figure 6.4: Morning light of medium intensity (AS)......................................85

Figure 6.5: Frequency Distribution of effect sizes measures by HDRS............................93

Figure 6.6: Frequency Distribution of effect sizes measures by AS..............................93

Figure 7.1: Treatment effect size (HDRS) of morning light vs. light intensity..................110

Figure 7.2: Treatment effect size (AS) of morning light vs. light intensity..................111

I. Introduction

Seasonal affective disorder (SAD), sometimes referred to as winter depression or winter blues, is the regular occurrence of depression in fall and winter with symptom remission in spring and summer (Rosenthal et al., 1984). While the concept of SAD has a long history in medicine, this clinical condition has not been seriously investigated until recently. Research to enhance an understanding of SAD and its treatment is valuable because of the widespread effect of SAD in clinical settings as well as other sectors of public health.

Bartko and Kasper (1989) reported that a large percentage of the 416 subjects from the general public experienced difficulties with seasonal change equivalent to those of subsyndromal SAD. Jacobsen et al. (1987c), in a study of phototherapy using SAD and normal subjects, reported that 20% of the normal subjects in their study complained of moderate to marked changes in mood and energy across the seasons, and winter was usually the least favoured season. Roob (1992) conducted a phenomenological study to identify the everyday life experiences of people suffering from SAD. She interviewed four female patients and found that SAD indeed hampered the quality of their vocational, family, and personal lives.

Key symptoms of SAD, such as daytime fatigue and somnolence, are important not only for job performance but also for occupational safety. Lavie et al. (1982) studied 1502 industrial workers and found a higher incidence of multiple work accidents among workers complaining of excessive daytime sleepiness. Lingjaerde et al. (1985) did an on-the-job survey in northern Norway and reported that more than 23% of people suffer from daytime sleepiness and a diminished work capacity during mid-winter.

Seasonal affective disorder in childhood and adolescence has been reported (Lucas, 1991; Rosenthal et al., 1986; Sonis et al., 1987), which could seriously compromise children's normal emotional development and school learning. From these reports, one should be able to comprehend the widespread negative effect of seasonal mood change on our daily functioning.

The general therapeutic effect of light on SAD has been widely demonstrated. As noted by Rosenthal et al. (1989), symptom remission usually started within four days of commencement of phototherapy, which was then followed by a complete alleviation of vegetative symptoms after one week of light administration. If light were withdrawn, the symptoms could return.

Despite the clinical success of phototherapy for SAD, many contentious issues about SAD and phototherapy exist in the field. Not only does the pathophysiology of SAD remain an unsolved puzzle, the mechanism as well as the optimum parameters of phototherapy, i.e. dose (intensity and duration), timing, and spectrum of light used in therapy have also been issues of heated debate. Identification of the optimum parameters of phototherapy is important for theoretical and clinical reasons. From a theoretical perspective, this offers insight into the pathophysiology of SAD and thus helps clear some mysteries surrounding SAD. From a clinical point of view, such an understanding is essential for identifying those clinical guidelines for phototherapy administration that offer promising treatment outcomes.

In view of the theoretical and clinical significance of identifying the optimum parameters of phototherapy, the present project is designed to reconcile disagreement of previous research findings of phototherapy studies and to identify a more unifying conclusion about the optimum parameters of phototherapy to be studied in future research. In order to achieve this aim, a meta-analytic methodology is employed to re-evaluate the qualitative and quantitative findings of previous phototherapy studies on phototherapy for SAD.

Meta-analysis employs a set of quantitative strategies to discover the consistencies of theoretical constructs and to account for the variability in studies with compatible research designs (Cooper & Hedges, 1994). Most importantly, by applying the statistical procedures and considerations endorsed in a meta-analytic review, data collected from different projects can be pooled for inferences of higher degree of generalisability than that achieved by individual projects of relatively small sample sizes. The process involves a thorough examination and evaluation of the findings and methodological discrepancies of a number of studies sampled for the analysis.

There are altogether eight chapters in this dissertation, including this one. Chapter 1 introduces the project. Chapters 2, 3, and 4 present the theoretical review of the present study. Areas of literature review include SAD (Chapter 2), phototherapy (Chapter 3), and meta-analysis (Chapter 4). Methodology is described in Chapter 5, followed by the presentation of the findings and the discussion of the results in Chapters 6 and 7. The conclusion is presented in Chapter 8.

II. Seasonal Affective Disorder - An overview

Seasonal affective disorder (SAD), though a relatively new term in the field of mental illness, is indeed not a new concept. Seasonal change in mood has been widely observed in the past, as reflected by the many poems that express feelings towards the "winter blues" syndrome.

Ah woe is me! Winter is come and gone,
But grief returns with the revolving year
(Berlin, 1984)

There's certain slant of light,
On winter afternoons,
That oppresses, like the weight
Of cathedral tunes.
(Berlin, 1984)

Early medical records of syndromes similar to SAD were identified in Hippocrates' era in 400 B.C.(Oren & Rosenthal, 1992). Easton (1990) reported records as early as Wong T'ai in 2700 B.C. Thereafter, isolated reports of symptoms similar to that of SAD were identified in medical literature. For example, Posidonius observed that "melancholy occurs in autumn, whereas mania in summer." (Roccatagliata, 1986). Kraepelin described SAD as a variant of manic-depressive disorder, with moodiness repeatedly setting in in autumn and passing over in spring (Rosenthal, 1986). Despite the fact that seasonal mood change has long been recognised, SAD has not been seriously examined until 1980s.

Clinical Features

The term 'Seasonal Affective Disorder' was first introduced by Rosenthal et al. (1984) to represent a cyclic affective illness characterized by recurrent episodes of depression in the fall and winter alternating with periods of euthymia or hypomania in spring and summer. Depressions are usually mild to moderate, although cases of severe depressions may be observed (Rosenthal & Wehr, 1987). The existence of hypomania or hyper-thymia is not an essential feature of SAD, as generally agreed upon, but rather the seasonality is the sole invariant defining characteristic of SAD (Blehar & Rosenthal, 1989a).

Apart from the usual features associated with a depressive mood, SAD is characterized by clinical symptoms such as hypersomnia, hyperphagia, anergia, carbohydrate craving, and weight gain (Jacobsen et al., 1987a), symptoms considered to be atypical in unipolar depression (American Psychiatric Association, 1994). These atypical symptoms may be related, but are not, however, strictly linked to one another. For example, Adam (1977) reported a positive correlation of sleep duration and body weight; nevertheless, a patient may present with hypersomnia, but without carbohydrate craving, or vice versa. Nonetheless, daytime fatigue appears to be a ubiquitous complaint of SAD patients (Terman, 1989).

Prevailing treatment for SAD is phototherapy, i.e. the therapeutic application of artificial light. There has been speculation that the severity and quantity of atypical symptoms may act as a predictor for response to light therapy, such that patients with relatively more atypical symptoms showed a better response (Meesters et al., 1993; Nagayama et al., 1991). To the contrary, Oren et al. (1992) propose that both typical and atypical depressive symptoms correlate with improvement after phototherapy. Other treatment strategies, such as pharmacological intervention (Dilsaver & Jaeckle, 1990; Dilsaver et al., 1990; Rosenthal, 1993), dietary control (Rosenthal, 1993; Wurtman, 1990), and psychotherapy (Rosenthal, 1993) have been discussed in the literature.

Other patterns of seasonally occurring mood change have been reported (Rosenthal & Wehr, 1987). For example, summer depressions have been observed in some people. The disease pattern is the reverse of that of SAD. Sufferers of summer SAD tend to experience depression in summer and remission in fall and winter (Rosenthal & Wehr, 1987). Having observed symptom remission of a patient with summer depression when placed in an air-conditioned apartment for several days (Rosenthal & Wehr, 1987), Wehr et al. (1989) speculated that summer depression may be triggered by environmental temperature and/or humidity changes. Because of the possible difference in the pathophysiology between summer and winter depressions, the present research project only focuses on winter depression so as to ensure the homogeneity of the question studied and hence the external validity of the inferences drawn.

Epidemiology

Clinical manifestation of SAD has been identified in many countries, East and West, and is estimated to affect about 5% of the population. Subclinical dysfunctional changes may occur in more individuals (Blehar & Rosenthal, 1989b).

Higher prevalence was reported by some clinicians/researchers. Hunt et al. (1992) reported that 15% of their sample demonstrated regular seasonal manic relapses. Gupta (1988), during his clinical practice in the Punjab, north India (27 39 N to 32 30 N latitude), estimated that about 10% to 15% of the patients with severe affective illness in the Punjab region were affected by SAD. O'Rourke et al. (1987) also reported a prevalence rate of 10%. Williams and Schmidt (1993) reported one-fifth of individuals seeking treatment for recurrent mood disturbances in northern Manitoba have SAD.

Terman (1988) conducted a population survey on the prevalence of seasonal mood change in New York City. Of over 200 responses, about 25% reported experiencing significant seasonal mood changes. A similar prevalence rate (27%) was identified by Kasper et al. (1989b) in their phone survey in the Maryland area. Boyce and Parker (1988) reported an even higher figure in their study. Eighty out of the 138 subjects studied reported depressive symptoms associated with a particular season. As suggested by Easton (1990), the inconsistency of these findings may suggest that SAD is a more severe expression of the naturally occurring seasonal variation in mood experienced by a fair percentage of the general population.

The prevalence of the condition seems to depend on latitude (Jacobsen et al., 1987c). Rosen and Rosenthal (1991) suggest that SAD may positively correlate with latitude. Rosen et al. (1990) report that the rates of SAD and subsyndromal SAD are significantly higher at the more northern latitudes for age groups over 35. Nevertheless, Sakamoto et al. (1993) propose that the operating variable here may not be latitude but in fact the number of hours of sunshine in a particular place.

Seasonal affective disorder has been more frequently observed in females than males (Kasper et al., 1989b; Lingjaerde & Reichborn-Kjennerud, 1993; Thompson & Isaacs, 1988), at about a 4:1 ratio (Hellekson, 1989). Of patients with winter depressions, 50 to 60 percent have first-degree relatives with major affective illness (Rosenthal et al., 1984), suggesting that familial factors play a significant role in predisposing the condition. The different prevalence rates for males and females may be due to possible differences in biochemical responses to climatic variables. For example, Buguet et al. (1988) studied the different adaptation mechanisms to increases in environmental temperature adopted by males and females. They concluded that males showed such an adaptation through a decrease in metabolism; whereas females showed mixed metabolic reactions to increases in environmental temperature.

The onset of SAD most often occurs in the second and third decades of life, with SAD onset in childhood or adolescence in some patients (Rosenthal et al., 1984; Sonis et al., 1987). Children and adolescents suffering from SAD also respond favourably to phototherapy (Blehar & Rosenthal, 1989a).

Diagnostic Criteria

The criteria for a diagnosis of SAD developed in 1984 included the following (Thase, 1989):

1. At least one lifetime episode of major depression, according to the Research Diagnostic Criteria (RDC);
2. A history of recurrent episodes of depression (major or minor episodes occurring in at least two consecutive winters) with onset in fall or winter and recovery by spring or summer; and
3. An absence of any other major psychiatric disorder.

Also, there should not be any psychosocial variable accounting for the regular changes in mood.

By 1987, more specific criteria for a seasonal pattern of mood disorders were incorporated into the DSM-III-R (American Psychiatric Association, 1987), which specified that recurrent depression had to start and end at dates within a 60-day window of one another.

Furthermore, the ratio of seasonal to non-seasonal episodes has to be at least 3:1. The condition can be a bipolar disorder, a recurrent major depression, or a depressive disorder not specified otherwise, as long as the seasonal pattern of SAD is demonstrated according to the specification (Haug, 1990). Because of the concern that the DSM-III-R definition could be too narrow for research and clinical applications - in particular, the 60-day window tends to be too restrictive and may exclude some true SAD sufferers (Takahashi et al., 1991), in DSM-IV (American Psychiatric Association, 1994), the 60-day window requirement was eliminated to broaden the definition of SAD so as to allow for more clinical judgement.

To refine the diagnostic criteria for SAD further, employment of additional criterion/criteria to differentiate true SAD from recurrent depression with an annual cycle similar to SAD (Thase, 1989) is important for clinical and research purposes. This addition would help achieve diagnostic homogeneity of the SAD population.

Measuring Instruments for SAD

Many tools have been employed for ascertaining the change in the severity of SAD in phototherapy studies. In particular, the Hamilton Depression Rating Scale has proven to be sensitive to clinical changes during phototherapy (Wehr & Rosenthal, 1989). The Hamilton Depression Rating Scale or versions of it (HDRS) (Hamilton, 1960, 1967) have been widely employed in research studies on SAD. Nevertheless, researchers also recognised the inadequacy of the HDRS in reflecting any change in the severity of those atypical symptoms characterising SAD. Therefore, Rosenthal and Heffernan (1986) came up with a measure of atypical symptoms of SAD to supplement the HDRS. Since then, Rosenthal and Heffernan's scale for measuring the atypical symptoms and its versions (AS) have been used in research studies on SAD. In 1988, William proposed a Structured Interview Guide for the Hamilton Depression Rating Scale. This, together with an addendum for measuring the atypical symptoms of SAD, has become the Structured Interview Guide for the Hamilton Depression Rating Scale - Seasonal Affective Disorder Version (SIGH-SAD), which included the 21-item HDRS as well as an 8-item AS. The SIGH-SAD has become a popular instrument used in research for SAD.

Pathophysiology of SAD

It is generally believed that decreased exposure to sunlight plays a significant role in triggering SAD in vulnerable individuals (Eastman, 1990); nonetheless, the true underlying mechanism(s) predisposing and precipitating SAD is(are) not yet known. Existing speculations of the pathophysiology of SAD were derived from two sources: 1. Data obtained from animal studies; and 2. Positive effect of light treatment on alleviating SAD symptoms (this will be discussed in the next chapter).

Clinical features of SAD, such as the vegetative symptoms of weight gain, decreased libido, hypersomnia, and the lack of energy, are reminiscent of seasonal physiological changes observed in animals. This observation suggests the possibility of adopting a hibernation model for SAD (Wirz-Justice et al., 1986), in which the symptoms of SAD are brought about by the change in seasonal rhythms controlled by climatic variables, especially the length of photoperiod (Murray, 1989). Based on this photoperiod hypothesis, it has been speculated that the manipulation of the length of daylight exposure, which subsequently acts to modify the neurochemistry of the body, may provide relief from SAD.

Light therapy has been used for treating SAD, and its effectiveness has been widely demonstrated (Rosenthal & Wehr, 1987; Rosenthal et al., 1988). Unfortunately this observation does not provide a proof unique for the photoperiod hypothesis, and many mysteries await to be solved. Did light work to extend the photoperiod, which subsequently changed the biochemistry of the body, as suggested above? Did it work on the human circadian rhythms, either by phase-shifting them or changing their amplitudes? Did photons absorbed during phototherapy trigger a series of biochemical reactions within the body not yet known by scientists? These questions remain the focal points of discussion in the field. As yet, the pathophysiology of SAD and the therapeutic mechanism of light are still unknown; several hypotheses have been put forth to explain the true mechanism of light for SAD, none of which is overwhelmingly conclusive. Major hypotheses of the etiology of SAD are discussed as follows:

Photoperiod. Animal studies showed that seasonal rhythms are cued to day length, or the photoperiod (Aschoff, 1981), which is transduced by the pattern of nocturnal melatonin (5-methoxy-N-acetyltryptamine) secretion by the pineal gland (Goldman & Darrow, 1983). Studies on Syrian hamsters have demonstrated that pineal melatonin secretion happens almost solely at night; the duration of nocturnal melatonin pulse is inversely related to day length, i.e. a long melatonin pulse signals short days leading to behavioral changes preparing the animals for the cold winter climate, e.g. weight gain, decreased activity, and inhibition of reproduction (Wade, 1989).

The similarity between the symptom constellation of SAD and those seasonal physiological changes seen in animals, e.g. weight gain, hypersomnia, and lack of energy, as well as the observation that bright light, while being able to alleviate SAD symptoms, is capable of suppressing nocturnal pineal melatonin secretion (Lewy et al., 1980), has led to the speculation that SAD was caused by abnormal body response to the seasonal change in day length. Treatment for SAD then is to lengthen the photoperiod by presenting bright artificial light in the morning and then in the evening. This is the very first model employed by the first published study on phototherapy for SAD (Lewy et al., 1982).

In order to test for the photoperiod hypothesis for SAD, Wirz-Justice et al. (1986) worked out the percentage of the patient population in her study suffering from depression in any one month. She found that the pattern had a high negative correlation (-0.94) with the length of photoperiod. This observation lends some support for the photoperiod model for SAD.

The findings of the study by Wehr et al. (1986), however, tend to work against the photoperiod model for SAD. In their study, they compared the therapeutic effect of long and short skeleton light, giving long and short photoperiod respectively. They observed that there was no significant difference between the two regimes and therefore concluded that the antidepressant responses to the short skeleton light regime served to argue against a photoperiodic mechanism for seasonal changes in SAD.

Further negative evidence is provided by Isaacs et al. (1988). They studied the therapeutic effect of photoperiod light administered in a morning-midday or morning-evening combination. Again, their results showed no significant difference between the two treatment regimes. There are other reports that photoperiod manipulation is not essential for the therapeutic effect of bright light for SAD (Hellekson, Kline & Rosenthal, 1986; James et al., 1985; Kripke, 1985; Lewy, Sack, & Singer, 1985; Terman et al., 1989b).

Although the trend of the findings tends to refute the photoperiod hypothesis, it is worth noting that studies providing negative evidence for a photoperiod model for SAD usually used a relatively small sample size; e.g. only 7 subjects were studied in Wehr et al.'s (1986) study. Therefore, the findings cannot be seen as conclusive. After all, seasonal change in photoperiod may adopt a more subtle, indirect role in the etiology of SAD.

Melatonin. In addition to speculating about a photoperiod model for SAD, clinicians and researchers also attended to the possible role of melatonin in the etiology of SAD. The melatonin hypothesis is based on the observation that bright light can suppress nocturnal pineal melatonin secretion (Lewy et al., 1980). It is further supported by the observation that administration of melatonin to SAD patients causes some of them to relapse while experiencing a remission from phototherapy (Rosenthal et al., 1985).

A way of examining the role of melatonin in SAD is to manipulate the strength of phototherapy under experimental situations. One would expect that the therapeutic effect of light would only be observed if light intensity is equal to or stronger than 2500 lux, an intensity found to exert a suppressing effect on pineal melatonin secretion (Lewy et al., 1980). In other words, dim light should have no significant therapeutic effect for SAD if a melatonin model for SAD were valid.

Studies have been conducted to compare the therapeutic effects of bright and dim light, but conflicting findings were reported. While bright light was found to be more effective than dim light in alleviating SAD symptoms in some studies (Blashko et al., p.c.; James et al., 1985; Rosenthal et al., 1984, 1985), other studies also reported that treatment efficacy of bright and dim light was similar. For example, Joffe et al. (1993) compared the effect of 60 lux, 600 lux, and 3500 lux of light emitted from a light visor in a multi-centre study of 105 subjects. No significant difference in the therapeutic effect of the three treatment regimes was identified.

Wirz-Justice et al. (1986) found that both bright and dim light showed similar therapeutic effects. Nonetheless, different light spectra were used for the experimental and control groups in this study, which may have confounded the findings.

Another way to test the validity of the melatonin hypothesis is by manipulating the time of phototherapy administration. Based on animal studies, light exposure in the middle of the day should have no effect on melatonin secretion and circulation, and therefore should be ineffective in alleviating SAD symptoms. These hypothetical relationships were refuted in the study conducted by Wehr et al. (1986). They found that light administered in the middle of the day, which had little effect on the already low daytime levels of melatonin, was an effective treatment for SAD. They therefore concluded that suppression of melatonin secretion was unlikely to mediate the antidepressant effect of phototherapy in those patients included in their study.

The melatonin hypothesis was refuted by Rosenthal et al. (1988), the originators of the melatonin hypothesis (Rosenthal et al., 1984). They found that the administration of atenolol, a beta-adrenergic antagonist that suppresses melatonin secretion, is relatively ineffective in the treatment of SAD. Nevertheless, the internal validity of this observation is questionable. The time of atenolol administration was not controlled, which could confound the findings significantly (Lewy & Sack, 1986).

Although the validity of the melatonin hypothesis has not been conclusively refuted, research findings tend to suggest an indirect role of melatonin in the etiology of SAD.

Phase-shifting. This hypothesis is based on studies of circadian rhythms, which are biological rhythms of an intrinsic period close to 24 hours (Aschoff, 1984) driven by an endogenous pacemaker thought to be located in the suprachiasmatic nucleus (SCN) of the hypothalamus (Moore & Eichler, 1972). Entrainment of circadian rhythms to the 24-hour precision is accomplished by phase-shifting, either advancing or delay, as a result of exposure to light (Pittendrigh, 1981). Photic information picked up by the retina travels to the SCN via the retinohypothalamic tract and geniculohypothalamic tract, via the ventrolateral geniculate nucleus, (Roelfsema, 1987), which then sends a circadian signal through a well defined neural pathway that terminates in the peripheral sympathetic innervation of the pineal (Moore & Lenn, 1972). Aschoff (1984) points out the association of circadian rhythms with other physiological processes, such as feeding behaviour, which is commonly dysregulated in SAD.

Phase-shifting of circadian rhythms varies in magnitude and direction, depending on the point in time of light exposure (Lewy & Sack, 1987). The relationship of light and phase-shifting is best described by a phase-response curve (PRC), which denotes that light presented in the morning phase advances the rhythm, and light presented in the evening phase delays the rhythm. Furthermore, light presented in midday does not have much effect (Lewy & Sack, 1987). These phase shifts compensate for each other and their net effect serves to compensate for the pacemaker's intrinsic (free-running) period to the 24-hour precision.

Honma et al. (1987) studied the responsiveness of free-running human circadian rhythms to a single pulse of bright light in a temporally isolated unit. They observed that a light pulse of 5000 lux administered in the early subjective day phase-advanced both the sleep-wake cycle and the rhythm of rectal temperature. They therefore concluded bright light could reset the human circadian pacemaker.

The effect of light on the melatonin rhythm (Lewy et al., 1989) suggests that melatonin can be the synchroniser of different seasonal rhythms. The suppression effect of bright artificial light on melatonin secretion (Lewy et al., 1980) has led to the speculation that the therapeutic effect of light for SAD was to phase-shift the abnormally delayed endogenous circadian rhythms so as to re-synchronise these rhythms. This model of SAD is termed as the phase-shift hypothesis (Lewy & Sack, 1986). Based on this phase-shift hypothesis, Lewy and Sack (1986) attempt to explain the observation of the preferential response to morning light by SAD sufferers by relating it to an abnormal phase delay of the pineal melatonin secretion rhythm in SAD. The antidepressant effect of morning light is viewed as the consequence of its ability to correct an intrinsic phase delay abnormality of the melatonin rhythm and ultimately other seasonal rhythms.

The observation that humans show a phase delay in plasma melatonin in winter (Lacoste & Wirz-Justice, 1989) provides some initial evidence for the phase-shift hypothesis. Elmore et al. (1993) explored the body temperature rhythms and diurnal type of 7 female SAD and 7 control participants and found that morning phototherapy advanced the body temperature rhythms of the female SAD subjects. Mizuma et al. (1992) conducted a case study on a 21-year-old male SAD patient and reported that his rectal temperature rhythm was advanced by the phototherapy, and his depressive symptoms were improved in proportion to the advancement of the rectal temperature rhythm. Avery et al. (1991) reported their findings in 1989 that the body temperature rhythm of the SAD subjects, when compared with nondepressed controls, was phase delayed. These reports lend further support to the phase-shift hypothesis.

Another relevant test for the validity of the phase-shift hypothesis is to examine the effect of phototherapy administered at different times of day. One would expect that morning light should be more effective than midday or evening night. Also, the therapeutic effect of morning light, by phase-advancing the melatonin rhythm, would be cancelled out by the phase delay effect of the evening light exposure.

In a study conducted by Terman et al. (1989a) using 2500 lux of light exposure, it was observed that subjects receiving morning light treatment (0600h-0800h), with or without evening light (1800h-2000h) exposure, showed varying degrees of symptom remission. In contrast, subjects receiving only evening light (1800h-2000h) or a combination of morning and late evening light exposure (2000h-2200h) failed to show symptom remission. Furthermore, Avery et al. (1990) and Sack et al. (1990) also found that morning light is significantly more effective in alleviating SAD symptoms than evening light. These observations have lent strong support to the phase-shift hypothesis.

A meta-analytic review by Terman et al. (1989b) reported that morning light produced higher remission rates than light administered at other times of the day. However, Avery et al. (1991) later reported Rafferty et al.'s observation that superiority of morning light may be an artifact due to the order effect when morning light was given first. Evening light would be as therapeutic as morning light if it were given first. Order effect was also reported by Wirz-Justice et al. (1986).

Negative evidence for the phase-shift hypothesis has also been reported. Meesters et al. (1993) successfully demonstrated that there was no significant difference in the therapeutic effect of morning and evening light. Furthermore, Rosenthal et al. (1985) and Eastman et al. (1992) reported the therapeutic effect of evening light. Also, Rosenthal et al. (1987c) reported the therapeutic effect of a morning-evening light regime for SAD. Wehr et al. (1986) reported their recent findings on a study of 48-hour profiles of hourly plasma melatonin levels and found no evidence of abnormally delayed rhythms in SAD patients.

Research findings of the validity of the phase-shift hypothesis are conflicting. Lewy and Sack (1986) argue against the reported negative evidence for this hypothesis by suggesting that the SAD population may be a heterogeneous one; some SAD patients may have their circadian rhythms abnormally phase advanced and some have the rhythms abnormally delayed. They further suggest that SAD patients should be phase-typed before inclusion in any study to verify the validity of the phase-shift hypothesis. As yet the phase-shift hypothesis remains unsubstantiated or refuted.

Photon-counting. This hypothesis stems from the speculation that a shorter photoperiod in winter deprives susceptible patients of sufficient quanta of light essential for maintaining a euthymic state. The neural mechanism underlying the photon-count hypothesis has not yet been identified. Based on the observation that animals raised under low illuminance levels showed a general elongation of rod outer segments and increased rhodopsin content (Terman et al., 1990a), it has been speculated that SAD may relate to rodshortening due to deficient photostatic adjustment, leading to decreased absorption of quanta of light. Henceforth, the photoperiod in winter needs to be extended to allow for the absorption of sufficient light energy for normal physiological and psychological functioning.

Some research findings are supportive of the photon-count hypothesis. Kasper et al. (1989a) studied the effect of different durations of light therapy on people with mild SAD symptoms. They observed that five hours of phototherapy was more effective than two hours. Furthermore, in a study by Sakamoto et al. (1993), it was concluded that decreased total hours of sunshine contributed significantly to the prevalence of SAD in depressed out-patients. Sayer, Marshall, and Mellsop (1991) also reported that admission rates for mania correlated significantly with sunshine hours in the month prior to admission. These research findings appear to lend strong support for the photon-count hypothesis.

The photon-count hypothesis appears to have a high degree of face validity. Nonetheless, its validity cannot be fully established until a dose-response relationship, i.e. increase in dose (duration and intensity) increases the antidepressant effect, is proven for phototherapy for SAD.

Neuro-chemical dysregulation. Neuroendocrinal dysregulation and neurotransmitter abnormalities in SAD have been actively studied lately. Dopamine and serotonin are neurotransmitters that some researchers speculate play a significant role in triggering SAD. Of the two neurotransmitters, serotonin has received the most research attention.

Serotonergic mechanisms have been known for their pivotal role in many vegetative functions disturbed in SAD. Serotonin plays an essential role in the initiation of sleep (Jouvet, 1969) and in weight and appetite regulation (Stunkard, 1980). In a study of post-mortem human brains conducted by Carlsson, Svennerholm, and Winblad (1980), neither sex nor age could account for the observed seasonal circadian changes in monoamine, especially a drop in serotonin levels from fall to winter, in the hypothalamus.

It has been speculated that brain serotonin plays an important role in the pathophysiology of SAD (Lam, Solyom, & Tompkins, 1991; Moller, 1992). O'Rouke et al. (1987) administered d-fenfluramine to seven SAD patients. Over 50% of the subjects experienced symptom remission. McGrath et al. (1990) conducted a study to compare the therapeutic effect of L-tryptophan, a precursor of serotonin in the brain, and phototherapy. They found that both treatment regimes were effective in alleviating SAD symptoms, and there was no significant difference between the therapeutic effect of the two. There was also a report of the beneficial effect of serotonin re-uptake blocker fluoxetine on SAD (Jacobsen et al., 1989). These findings are supportive of the role of serotonin in the etiology of SAD.

Further evidence of a serotonergic dysregulation in SAD is provided by Rosenthal et al. (1987a). Based on the theory that dietary carbohydrates can have an impact on central serotonin metabolism, they examined the effect of two iso-caloric meals (high protein and high carbohydrates) on SAD. The SAD subjects reported decreased drowsiness after the carbohydrate meal, whereas the normals reported increased drowsiness.

Ohi et al. (1988) studied the development of circadian rhythms in rats with lesions in the serotonergic system and concluded that a serotonergic system did not seem to be essential for the generation of the endogenous rhythm nor the photo-entrainment of overt circadian rhythms, but it did seem to participate in the development of corticosterone rhythms during the early stage of life.

Moller (1992) reported that consumption of carbohydrates increases the plasma content of tryptophan, henceforth, serotonin synthesis in the rat brain. Therefore, they propose that excessive carbohydrate intake by SAD patients may reflect a self-medication that temporarily relieves the vegetative symptoms via an increased central serotonergic activity.

Other hormones, which show seasonal variation in their levels, may link to the etiology of SAD. Prolactin and thyroid hormone levels were reported to be abnormal in SAD patients (Skwerer et al., 1989). Jacobsen et al. (1987b) and Depue et al. (1989) observed abnormal basal plasma prolactin levels in SAD patients. Both of the groups interpreted this observation as an indication of dopamine abnormalities.

Other possibilities of the etiology of SAD are the dysregulation in the hypothalamic-pituitary-adrenal axis giving rise to the various atypical vegetative symptoms observed in SAD (Skwerer et al., 1989). Alpha-2 and cholinergic receptors may be involved in the etiology of SAD, as Dilsaver and Majchrzak (1988) observed that rats exposed to bright light demonstrated blunted hypothermic response to clonadine and nicotine, a phenomenon seen with other pharmacological treatments for depression.

Further work to discover the role of different neurotransmitters and hormones in predisposing and precipitating SAD may offer important insight into the etiology and treatment of the condition. Readers are reminded that the above discussion of neuro-chemical dysregulation in SAD is only a brief summary of the recent findings in the field. Detailed elaboration of the neuro-chemical nature of SAD is beyond the scope of the present dissertation.

SAD - A Distinct Clinical Entity

Although SAD possesses a high degree of face validity of seasonality and recurrence of winter depression, the claim that SAD is a distinct diagnostic clinical entity separated from other mood disorder subtypes remains controversial. Some researchers have suggested that SAD could have arisen as a result of the screening technique that defined it. Therefore, it is necessary to first establish that recurrent depression is non-randomly distributed before the seasonal nature of SAD can be accepted unequivocally as evidence of a syndrome (Mrosovsky, 1989). This speculation is not supported by the findings of Kasper and Kamo (1990), which show that major depression is not necessarily associated with a higher degree of seasonality.

Evidence to support SAD as a distinct diagnostic entity has been provided by different researchers/clinicians in the field. Rosenthal et al. (1984) point out that the outstanding clinical features of patients with SAD are their apparent sensitivity to changes in season and latitude and the approximately annual occurrence of their affect episodes. Thase (1989) suggests that the natural history of predictable modulation of moods associated with travelling to sunny locales, together with mood variation between sunny and overcast days reported by SAD sufferers, but not people with recurrent depression, provides evidence for the uniqueness of SAD.

Further evidence for SAD as a distinct diagnostic subtype is provided by Hardin et al. (1991). They employed the Seasonal Pattern Assessment Questionnaire (SPAQ) to discern two normal and six clinical populations, including the SAD population. They reported that the SPAQ successfully discriminated SAD subjects from normal controls, bipolar and major depressive populations. The eating disorder population demonstrated unexpectedly high scores on the SPAQ, which may suggest a link between the two conditions. Bartko and Kasper (1989) conducted a cluster analysis of the responses of 416 subjects from Montgomery Country, Maryland, USA, on SPAQ and identified a distinct cluster for SAD.

Wirz-Justice et al. (1986) reported close overlaps of the clinical picture between SAD and atypical and anergic bipolar depressions, implying that SAD may be a variant of other forms of affective disorders.

Nonetheless, the seasonality of the samples involved in the study was not examined, which can be crucial to decipher the validity of the claim. Mueller (1986) suggests that although SAD resembles an atypical bipolar disorder in a lot of ways, the hallmark that distinguishes SAD from atypical depression is that patients with SAD always reported anhedonia and low energy level in the fall-winter period and hyperphoria, racing thoughts, and agitation in the spring-summer period.

A study was conducted by Allen et al. (1993b) to compare the symptom profile of SAD and non-SAD mood disorders using a matched sample of 34 subjects. The findings showed that hypersomnia, hyperphagia, and weight gain occurred significantly more frequently in the former than the latter groups. Alcoholism also occurred significantly more often in the family history of patients with SAD than with non-SAD mood disorders.

James et al. (1986) studied the dexamethasone suppression test (DST) in SAD and found that only two out of the twenty subjects in their study showed abnormal responses to DST. They then suggested that normal suppression of the hypothalamic-pituitary-adrenal axis by dexamethasone could be a feature differentiating SAD from other psychiatric disorders. These observations are some evidence supporting the suggestion that SAD is a distinct diagnostic entity.

Phototherapy was reported to be an effective treatment for SAD (Hill, 1992). Easton (1990) points out that almost all of the data of phototherapy studies for SAD have been collected from small, open, uncontrolled studies with no placebo controls, and such anecdotal evidence cannot conclusively demonstrate the validity of SAD. In fact, Eastman et al. (1992, 1993) suggest that most of the antidepressant effect of light could be attributed to placebo effects, and treatments could only be considered effective if they produced improvements beyond that attributable to placebo effects. To make the situation worse, the wide publicity of phototherapy and SAD makes it hard to find naive subjects. In fact, Sakamoto et al. (1993) suggest that the vegetative profiles of SAD patients who do not have any prior knowledge of SAD and those who are recruited via the media can be quite different.

To answer scepticism about the effectiveness of phototherapy for SAD, Rosenthal et al. (1985) reported the observations that there was generally a time lag of approximately two to four days for both remission after initiating light treatment and relapse following light withdrawal. Also, the effect of light therapy tended to be long lasting, and the difference between the therapeutic effects of bright and of dim light remained quite stable with time. Based on these observations, they suggest that a placebo explanation of the therapeutic effect of light would not be plausible, since a placebo tends to result in a more rapid and variable time course of response and relapse, a gradual decline in treatment efficacy with time, and a variable difference between treatment effect of bright and dim light.

Another piece of evidence of the validity of the therapeutic effect of phototherapy for SAD is provided by Bauer et al. (1994). In their study, the SAD patients were not cued to expect development of hypomanic symptoms during light treatment. The observation of this undesirable effect of phototherapy in one-third of the 12 SAD subjects suggested that a placebo response to light was unlikely.

Terman (1993) also advocates for the fact that SAD is a distinct diagnostic entity. He observed that there were selective predictors of clinical response to phototherapy by SAD subjects, which suggested that a placebo explanation for the therapeutic effect of light was unlikely. Rabkin et al. (1987) reported that the placebo response reached its minimum in winter and its peak in summer, which is another reassuring evidence of phototherapeutic responses of SAD patients.

The question remains whether light has a truly antidepressant effect or simply acts as a conditioned stimulus. As suggested by Isaacs et al. (1988), SAD patients may observe their depression as due to a lack of light. Light then serves as a conditioned stimulus, the response being elevation of mood. Richter et al. (1992) compared the treatment efficacy of imagery light through hypnosis and real light through phototherapy for SAD. They observed that both treatments were equally effective initially, but the therapeutic gain of the hypnotic group gradually disappeared one week after treatment withdrawal. This suggests it is unlikely that light works as a conditional stimulus, since the antidepressant effect of light has proven to be more long lasting (Rosenthal et al., 1985) than that observed in the hypnotic group.

A narrative report by a SAD patient in Canada, who was one of the few people starting light therapy in the early 1980s when not much information about SAD was disseminated, lends additional credence to the true therapeutic effect of light for SAD patients. According to her, she had not heard of the term SAD or winter depression when she started receiving light treatment. She was in fact very sceptical about the use of light for her depression. Remission from the depressive symptoms after phototherapy not only eliminated her scepticism about the therapeutic effect of light but also convinced another psychiatrist, who initially found it hard to believe in the antidepressant effect of light.

Despite the amount of convincing evidence suggesting that SAD is a distinct diagnostic entity, SAD is still being received with scepticism. A possible reason for this scepticism is that, unlike other physical conditions for which a tangible pathogen can be observed and tested, the etiology of SAD has not yet been identified. Future scientific endeavour is urgently required to unfold the pathophysiological mechanism of the condition so as to verify the validity of SAD as a distinct diagnostic category of affective disorder.

III. Phototherapy for SAD

Sunlight reaches levels of about 100000 lux (Thorington, 1985), whereas artificial indoor light is rarely over 500 lux. The discovery that human biological rhythms are synchronised with sunlight yet not confounded by ordinary indoor light suggests that artificial light of high intensity may be employed to manipulate these rhythms in treating circadian disorders. This kind of treatment is referred to as phototherapy.

Phototherapy, as described by Bielski et al. (1992), falls within the realms of photobiology, the science of the interaction of light and living matter, and photo-medicine, the clinical application of light as a therapeutic agent. Recently, phototherapy has been widely applied in treating mood disorders in various clinical and research settings.

The use of light for treating depression is not a new idea. According to Wehr and Rosenthal (1989), the earliest record of phototherapy for depression was in the Greco-Roman era. Recent history of phototherapy began in the early 19th century when Esquirol attempted to use light to treat depression.

Dr. Federick Cook, who was ship's doctor on the Belgica in late 1800, recorded the adverse effect of darkness and the therapeutic effect of light (Jefferson, 1986). Booker and Hellekson (1992) cited Dr. Cook's record:

> The darkness, cold, and isolation then drive the mental faculties on to melancholy...The earliest effects become manifest in the mental realm. The physical changes become evident slowly, often not at all until near the end or at sunrise of the next year. (p.1176)

In 1946, Marx also reported the antidepressant effect of light (Wehr & Rosenthal, 1989).

Phototherapy for SAD

The idea of phototherapy for SAD did not flourish until an engineer documented his own seasonal mood swings for fifteen years. He then hypothesized that changes in environmental light might have influenced the course of his condition (Lewy et al., 1982; Rosenthal et al., 1983). Later discovery that human melatonin rhythms, controlled by sunlight, can be manipulated by exposure to bright artificial light of about 2500 lux (Lewy et al., 1980), suggests that light may act as an antidepressant agent for this recurring seasonal depression.

The underlying therapeutic mechanism of phototherapy for SAD is not yet known. Based on the proposed hypothetical pathophysiological mechanisms of SAD, two popular approaches are adopted to explain the phototherapeutic effect for SAD: the circadian and the photoperiodic approaches. Pittendrigh (1989) thought that the artificial distinction between these two approaches lacked real meaning because photoperiodic responses of virtually every organism were somehow mediated by the circadian system. He commented:

> ...animal studies have clear utility in evaluating and developing the widespread assumption that SAD and its phototherapy have a circadian basis. The most significant feature of SAD is its seasonality: The winter state of the circadian system, induced by natural short [sic] photoperiods, is abnormal in SAD patients, but its summer state, induced by longer natural day length, is essentially normal in the same individuals. Phototherapy, in extending the short winter day, returns the patient's circadian system to its essentially normal summer state. (p.102)

With respect to the prediction of clinical success of phototherapy for SAD, Terman (1993) proposes that the strongest positive predictor is the atypical balance score, which is expressed as the percentage of the atypical score on the total SIGH-SAD score. The strongest negative predictor, on the other hand, is the overall HDRS severity.

Light Source

Light fixtures of varying sizes have been used in phototherapy. The most frequently used light source has been Vita-Lite, full-spectrum fluorescent light. As reported by Rosenthal and Wehr (1987), this light box contains six or eight 40-watt tubes inserted into a rectangular metal fixture of 2 by 4 feet, with a reflecting surface behind and a plastic diffusing screen in front of those light tubes. The light box is usually placed approximately 3 feet away from the user, who is advised to stare at the light source for a few seconds every minute. The intensity of light measured at 3 feet from this light source is about 2500 lux. Apart from this 2500 lux light box, there is also a 10000 lux light box in the market (Rosenthal, 1993).

Recently a head-mounted light-therapy device or "light visor" has been developed by researchers in the National Institute of Mental Health (Rosenthal et al., 1993). One of the advantages of the light visor is that the light-emitting area takes up only the upper visual fields, and the users should be able to see their surroundings. Therefore, the design and technology of this newly developed light visor should enable maximum absorption of the emitted light, but of virtually no ultraviolet (UV) waves, by the user. Dr. C. Blashko (p.c.), a psychiatrist practising in Edmonton, Canada, commented that some of his patients reported the inconvenience of using the light visor because they tended to run into surrounding objects while wearing the visor.

Dosing Dimensions of Phototherapy

According to photobiological principles (Bielski, Mayor, & Rice, 1992), biological effects of light are usually confined to a narrow-wave band of the spectrum, and are usually dose-dependent. As yet, parameters of light used in therapy for SAD are contentious. Many studies have been conducted to examine individual parameters of phototherapy, but conclusive findings are lacking. Determining the critical parameters of light exposure is important because it helps clarify the mechanisms underlying light therapy so as to bring about improved strategies and therapeutic devices for phototherapy for SAD.

Terman et al. (1989b) attempted to identify optimum parameters of phototherapy by conducting a meta-analytic review of data from 29 studies conducted in 14 centres. They concluded that bright light was more effective than dim light, and morning light was more effective than evening light. Unfortunately, the validity of these conclusions is questionable because issues such as methodological discrepancies as well as the quality of each study were not addressed when data were pooled in their study. Conclusions thus drawn were vulnerable to threats to both internal and external validity.

Parameters of phototherapy addressed in the present dissertation are: light intensity, timing of phototherapy administration, and light spectrum used in phototherapy.

Intensity and duration. The photochemical effect of light requires that light be delivered at sufficient intensity and administered for a sufficient duration (Rosenthal & Wehr, 1987). Terman et al. (1989b) suggested that duration of light exposure works in interaction with light intensity. Their assumption is based on the observation that patients who respond to two hours of morning exposure at 2500 lux, but who relapse with a reduced duration of 30 minutes, show full and enduring remissions at 30 minutes of phototherapy at 10000 lux. This phenomenon is described as dose-response relationship of phototherapy for SAD, with dose being defined as the total amount of radiation delivered (Bielski et al., 1992).

The intensity of light used in phototherapy studies is usually 2000 to 2500 lux, based on the understanding that such intensity is effective in suppressing nocturnal melatonin secretion (Eastman, 1990). Brighter light of 7000 to 10000 lux is more popularly used now after Terman et al. (1989a) reported that strong light required less time for symptom remission. Dim-light sources are about 100 to 400 lux (Rosenthal et al., 1989).

Rosenthal et al. (1984, 1985) suggested that light dimmer than 300 lux was not effective for SAD. Lam et al. (1991c) reported that dim light of 500 lux did not produce statistically significant treatment effect on SAD. Other researchers (Lam et al., 1989; Terman et al., 1989b) also reported the insignificant antidepressant effect of dim light.

To the contrary, Wirz-Justice et al. (1986) reported that bright (2500 lux) and dim (300 lux) light were equally effective in treating the SAD subjects that they studied, but observed that the duration of remission was longer for bright than dim light. A multi-centre study (Joffe et al., 1993) reported a similar antidepressant effect of light of 60 lux, 600 lux, and 3500 lux emitted from a light visor. Eastman et al. (1992) also reported that low intensity light was an active treatment agent for SAD.

The insignificant clinical value of dim light has been widely recognised, and, in fact, the observed therapeutic value of low intensity light is likely brought about by a placebo effect (Blashko, p.c.). The discrepancy of research findings of the antidepressant effect of dim light may be due to methodological discrepancies and/or measurement errors, e.g. small sample sizes.

Durations of 2 and 4 hours of light exposure are usually employed for phototherapy studies. It has been suggested that the rate of improvement increased with increasing duration (Terman et al., 1987). Wirz-Justice et al. (1987) showed increased efficacy from increased duration. Nonetheless, the same conclusion could not be reached by some other groups (Blehar & Rosenthal, 1989a).

In the present meta-analysis, only the treatment efficacy of different light intensity is addressed. The effect of duration of phototherapy is not statistically analyzed because the available data are insufficient for such an analysis. Nevertheless, a review of those articles of phototherapy for SAD collected for the present analysis suggests that the duration of phototherapy tends to be quite constant in different treatment regimes. Light given in the morning, midday, or evening tended to be of 2 to 3 hours in duration.

Only one study used a pulse of light of 0.5 hour (Avery et al., 1993). Duration of light given in both morning and evening tended to be 4 to 5 hours in total. With this pattern identified, it is assumed that there is no significant difference in the average duration of morning, midday, and evening phototherapy, and the average duration of the morning-evening phototherapy regime tends to double that of morning, midday, or evening phototherapy.

Timing. The prevailing hypotheses of the etiology of SAD - the photoperiod, melatonin, phase-shift, and the decreased amplitude hypotheses - all suggest that timing of phototherapy is critical for determining its therapeutic effect. The effect of morning, midday, evening, morning-evening light exposure has been examined in studies using different methods, but conflicting findings have been reported.

Avery et al. (1991), Terman et al. (1987), and Sack et al. (1990) found that morning light was superior to evening light in their studies of phototherapy for SAD. To the contrary, Wehr et al. (1986), Hellekson et al. (1986), Eastman et al. (1992), Isaacs et al. (1988), and Jacobsen et al. (1987a) reported that timing of light therapy was not important for the therapeutic response.

As yet, the discrepancy is unsolved, and optimal timing for phototherapy administration remains undetermined. The identification of optimal timing of phototherapy is not only important for an understanding of the pathophysiology of SAD, it may also contribute to administration convenience, leading to higher compliance of treatment by SAD patients. For example, if light were found to be effective regardless of the time of administration, patients would then have the freedom of choosing a convenient time for light therapy. As a matter of fact, morning and evening light tend to interrupt daily routines differently (Eastman et al., 1992).

Spectrum. The original study design of phototherapy for SAD used a bank of full-spectrum fluorescent bulbs behind a plastic diffusing screen within a rectangular box (Rosenthal et al., 1989). Since then, there has been speculation that full-spectrum light may not be essential for treating SAD.

Treatment efficacy of different light spectra has been studied, which included full-spectrum light with or without the ultraviolet waves, cool white, red wave, green wave, and incandescent light. Cool white light is fluorescent light with a large output of power in the green and yellow wave bands and a small amount of UV emission. Incandescent light is primarily yellow waves with negligible UV emission (Lam et al., 1991c).

Bielski et al. (1992) compared the treatment effect of full-spectrum and cool-white fluorescent light and found that they were equally effective for SAD. Brainard et al. (1990) conducted a study to investigate the treatment efficacy of white, red, and blue light for SAD. They found that white light had greater therapeutic benefit than red or blue light. Nonetheless, the authors realised that the sample size used was too small (n=18), such that generalising the findings to other populations might be risky.

Oren et al. (1991) studied the treatment efficacy of green and red light and concluded that green light was as effective as white light, and both of them had a superior antidepressant effect to that of red light. They further reported that UV light was not critical for the treatment effect of phototherapy for SAD. Their report supported the speculation that the UV light band can be eliminated completely without reducing the antidepressant effect of phototherapy for SAD (Terman, 1989).

Lam et al. (1991c) compared the antidepressant effect of 2500 lux full-spectrum fluorescent light, with and without the UV spectrum. They found that UV light was more effective for the typical depressive symptoms, e.g. insomnia, appetite loss, weight loss etc. The UV-block condition, on the other hand, produced significant improvement on atypical symptoms that characterise SAD. Nevertheless, in another study by Lam et al. (1992) of the treatment efficacy of the UV-A and UV-block treatment conditions, they found that both conditions were effective for reducing typical and atypical symptoms.

It seems that spectral properties of phototherapy for SAD are not yet known, and further research to solve this puzzle is needed. Identification of the optimum light spectrum for treating SAD is important for two reasons. The first is that it will provide an essential guideline for excluding/including the potentially toxic UV light in therapy for SAD. The second is that it will allow for the identification of photo-pigments and photoreceptors involved in the transduction of light into nerve impulses in the retina, which may offer insight into the pathophysiology of SAD.

Side Effects of Phototherapy

Rosenthal and Wehr (1987) reported that patients undergoing phototherapy sometimes complained of irritability, eyestrain, headaches, or insomnia. Also, hypomania responses were observed in several cases. The subjects in the study conducted by Wirz-Justice et al. (1986) reported that white light gave hypomanic activation, irritability, headache, and nausea; whereas dim yellow fluorescent light gave headache, nausea, agitation, irritability, and worsening depression. Levitt et al. (1993) reported that headache and eyestrain were some side effects of phototherapy.

There has been concern that light therapy exposes users to the harmful effects of UV light. Potential harmful side effects of phototherapy to human eyes were discussed by Terman et al. (1990d, 1991). Damage to rod and cone photoreceptors in monkeys after prolonged exposure to UV light has been reported. In humans, long-term UV exposure can lead to cataract formation, skin cancer, and retinal degeneration (Lam et al., 1992). Furthermore, White and Fisher (1987) reported that daily exposure to bright light in the morning produced greater photoreceptor loss than daily afternoon exposure.

With respect to this concern, Wirz-Justice et al. (1986) reported that ophthalmological investigation of the subjects showed no changes in visual function after light treatment. Bielski et al. (1992) reported that UV emission from fluorescent lamps in phototherapy did not exceed phototoxic levels by any current national standard.

The possibility of photochemical lesion as a result of exposure to the heat energy produced by the infrared component of the light spectrum during phototherapy has been expressed. Hellekson et al. (1986) argued that the heat energy in phototherapy was far below the threshold of 400 J/cm2 (Ham et al., 1979) for mild photochemical lesions of the retina.

Despite the suggestions that phototherapy rarely leads to irreversible physiological change in the human retina, it is recommended that careful ophthalmological evaluations before and after phototherapy should become a routine practice in settings administering phototherapy (Waxler et al., 1992).

IV. Meta-Analysis - Integration of research findings

In human history, knowledge has been accumulated through generations of continuous inquiry and research. Analysis and integration of existing data are essential for guiding future investigations to bring about further advancement of knowledge in a particular field. Traditionally, scientific researchers have relied solely on qualitative literature reviews for data summary. This qualitative mean of data integration, though essential, has its shortcomings.

Jackson (1978) attempted to examine the inadequacy of these traditional practices and methods of data integration adopted by research reviewers and synthesizers in the field of social science. He concluded that reviewers tended to rely too heavily on statistical significance of individual results and frequently failed to examine critically the evidence, methods, and conclusions of previous reviews on the same or similar topics. Validity of the conclusions drawn was questionable. Moreover, possible relationships between the characteristics of studies and research findings were frequently overlooked. Jackson (1980) commented:

> It appears that relatively little thought has been given to methods for doing integrative reviews. Such reviews are crucial to science and social policy making yet most are done far less rigorously than is currently possible. (p.459)

Vote counting method, developed by Light and Smith (1971), was supposed to be a more scientific method for data integration. Under this method, each study in effect casts a vote for or against the efficacy of the treatment. Nonetheless, Hedges (1986) pointed out that the vote counting method was a misleading inference procedure.

> Vote-counting not only has very low power to detect effects under the conditions in which it is usually used, but the power may actually decrease (tending to zero) as the number of available studies increases! (p.356)

Under the pressure of burgeoning research findings, the inadequacy of the narrative techniques of research review and integration and the vote counting method becomes more and more obvious.

In 1976, Gene Glass coined the term "meta-analysis" to represent a new concept and systems of data integration. He defined meta-analysis as

> the analysis of analyses...the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings. (Glass, 1976, p.3)

It is a method which provided statistical integration of empirical studies of a common phenomenon. Glass, McGaw, and Smith (1981) further explain that meta-analysis is not merely a methodological approach of summary of data of separate studies; rather, it requires the application of analytic techniques to the task of quantifying individual studies, and a perspective that takes advantage of available measurement and statistical techniques. According to Glass et al. (1981), meta-analysis is not simply a statistical approach to literature review but an approach that demands good evaluative skills, careful decision making, and many techniques of measurement and statistical analysis.

Miller and Pollock (1994) suggest that adopting a meta-analytic approach for theory verification offers a level of analysis that is difficult to achieve in a single study. It not only offers a high power of quantitative integration across temporal horizons, but also helps minimize the negative effect of logistical constraints often faced by single studies.

Meta-analysis involves the examination of effect sizes of each study for data integration. Effect size itself is a scale-free index of effect magnitude (Glass, 1976) developed from Cohen's (1969) concept of standardized mean difference. It is defined as the mean difference between experimental and control groups divided by within-group standard deviation (Glass et al., 1981). Mathematical derivatives of effect size will be further explained in the next chapter.

Many refinements of the meta-analytic methodology have been made since 1976. The restrictive view of meta-analysis originally proposed by Glass has been further expanded. Hedges (1986) uses the term "meta-analysis" in a broad sense to connote:

> any literature review that makes explicit use of quantitative methods to express the results of studies or to combine those results across studies. (Hedges, 1986, p.353)

This broad definition of meta-analysis advocated by Hedges is adopted in the present meta-analytic review of phototherapy for SAD.

V. Method

The aim of the present meta-analytic review of studies of phototherapy for SAD is to examine whether phototherapy really helps alleviate symptoms of SAD. Treatment efficacy, expressed as treatment effect size, of various parameters of phototherapy, namely intensity and timing of light administration, was investigated. It is believed that answers to these questions would help settle some of the prevailing theoretical disputes in the field, and lead to the establishment of effective treatment guidelines on phototherapy for SAD and a better understanding of the theoretical constructs of phototherapy and SAD.

Spectral properties of phototherapy were also examined. Unfortunately, the sample for this analysis was small as well as heterogeneous, which created a significant threat to the internal and external validity of the findings. These findings are, therefore, presented and discussed in Appendix 6 rather than being included in the main discussion of the present dissertation.

The meta-analysis methodology hereby adopted is based on the model of meta-analysis proposed by Cooper and Hedges (1994). The entire research process is divided into four stages: The first stage is problem formulation, the second is data collection, the third is data evaluation, and the fourth is data analysis. While conducting this research project, special attention was paid to control and minimize the impact of those major shortcomings common for a meta-analysis methodology. These shortcomings are grouped into the following four categories (Glass et al., 1981):

1) The "apples and oranges problem", which means the mixing of different measures together.
2) Use of data from low quality studies.
3) Selection bias in published research work.
4) Lumpy data, which means that multiple results derived from the same study lead to inter-dependency of the data in analysis.

The steps involved in each stage are delineated and discussed as follows:

Stage I - Problem Formulation

Preliminary understanding of the theoretical construct of SAD allowed for the generation of three a priori hypotheses presented below. Narrow constructs were employed in the process of hypotheses verification so as to tackle the common criticism of "mixing apples and oranges" for a meta-analysis methodology (Hedges, 1986). Due to insufficient data available, thorough examination of the spectral properties of phototherapy was impossible. Nonetheless, a preliminary analysis was conducted, and the results are reported in Appendix 6.

1)Light is effective in alleviating symptoms of SAD. Two separate analyses were conducted for studies of phototherapy, the Light Group, and for studies that used 'no light condition' as the control, the No Light Group. The generated effect sizes were then compared so as to verify this hypothesis.

2)Light intensity varies positively with treatment effect size. This hypothesis implied that the higher the intensity of light used, the stronger the anti-depressant effect would be. To verify this hypothesis, studies were first clustered into three groups according to their respective light intensity used in the studies. These three groups were: dim light (</=600 lux), median light (1700 to 3500 lux), and strong light (6000 to 10000 lux).

The blocking method was employed for the analysis. The hypothesis was tested in a two-stage process. The first stage involved the sorting of all studies included in the present analysis into four groups: morning, midday, evening, and morning-evening light groups. The second stage was to compare treatment efficacy of dim, median, and strong light within each group.

In this review, three separate analyses were conducted to verify this hypothesis. The first two involved the comparison of the treatment effect of strong, medium, and dim light intensity, measured by the HDRS and the AS, within the morning light group. The third analysis examined the treatment effect of dim and medium light intensity, measured by the HDRS, in the morning-evening light group. The relationships of treatment efficacy and light intensity of the midday and evening light groups were not examined because the available data were insufficient for such an analysis.

3)Morning light is a more effective treatment regime than light administered at any other time of the day. Studies using median light intensity (1700 to 3500 lux), which made up about 80% of all studies collected for the present meta-analysis, were included in the first analysis to verify this hypothesis. The appropriate studies were divided into four groups according to the timing of light therapy, namely morning, afternoon, evening, and morning-evening light. The treatment efficacy, measured by HDRS, was compared among the four groups.

The second analysis involved the morning, evening, and morning-evening light groups. Treatment efficacy of these groups, measured by the AS, was compared to identify the impact of timing of phototherapy on the atypical symptoms of SAD.

The third analysis involved those studies using dim light intensity in the morning and the morning-evening light groups. Treatment efficacy of these two groups, measured by the HDRS, was compared.

Stage II - Data Collection: Searching the Literature

Published and non-published studies of phototherapy for SAD included for further analysis had to meet two inclusion criteria for this meta-analysis. The first one was that parameters of light therapy were experimentally manipulated under between-subjects design, i.e. random assignment of subjects to experimental and control groups, or within-subjects design, i.e. single group repeated measures design. Narrative reports and single subject research reports were excluded in order to preserve the power of generalisability of the present findings.

There have been many myths about the within-subjects design (Hunter & Schmidt, 1990) that lead to it being rejected in a meta-analysis. Hunter and Schmidt (1990), however, argue that under most situations the within-subjects design is far superior to the between-subjects design in terms of its statistical power and urge meta-analysts to use the more powerful within-subjects design whenever possible.

The second criterion for inclusion was that measurement tools used for the dependent variable, i.e. the severity of the SAD symptoms, had to be versions of the Hamilton Depression Rating Scale (HDRS) (Hamilton, 1960, 1967) and/or measurement for atypical symptoms proposed by William (1988) or Rosenthal and Heffernan (1986) or versions of them (AS).

Representativeness of the studies selected. The representativeness of the sample is crucial for valid generalizations of the findings of a meta-analysis (Hedges, 1986). This implies the importance of obtaining a representative sample of relevant studies for a meta-analysis. To ensure the representativeness of the studies collected for this review, i.e. to minimize the effect of missing data as well as publication bias, which is one of the major criticisms of a meta-analysis methodology (Glass et al., 1981), both published and unpublished data were solicited.

The "file drawer problem" (Rosenthal, 1989), i.e. the problem of the tendency for studies supporting the null hypothesis of no significant results to be more likely to be buried away in file drawers (Wolf, 1986), is believed to be minimal for the present meta-analysis at least for two reasons, both of them related to the young history of phototherapy and SAD. Unlike some other fields where research is driven by well-established theory, thereby creating a tendency to publish findings in support of the well-received theory in that field, the theoretical constructs of phototherapy and SAD are far from being established. This suggests that clinicians and researchers are less inhibited in terms of publishing significant or insignificant research findings because either direction might be a true explanation of the phenomena. Moreover, the young history of this newly identified research area should prevent the stockpiling of significant numbers of insignificant data sets, thereby avoiding a sample bias that would jeopardise the validity of the findings of the present meta-analysis.

In this meta-analysis, published articles were located through a thorough literature search of the following sources:

1. Reference database systems including PSYLIT and MEDLINE available in the libraries of the University of Alberta
2. Indexed bibliography published by the Society for Light Treatment and Biological Rhythm, which provided about three thousand references covering the areas of light therapy, biological rhythm, and seasonal affective disorder
3. Relevant chapters in published books, which

discussed medical application of light, biological rhythm, and seasonal affective disorder

4. Bibliography lists of books and journal articles located in steps 1 to 3
5. Personal communications with prominent researchers and colleagues in the area

Unpublished data were solicited from clinicians and researchers in the field listed in Norman Rosenthal's (1993) book on SAD.

Stage III - Data Evaluation and Coding

Data evaluation. The collected published and unpublished studies were screened for study quality. Glass et al. (1981) suggest that difference between the average effect sizes of high and low quality experiments is minimal. Therefore, articles should not be excluded based on the quality of research design. Hedges (1986) argues that study quality does relate to treatment effect size. Also, variance components of effect sizes of studies with poor experimental control tended to be greater than those of highly controlled studies.

Hedges's argument is more convincing; as well, it helps answer one of the major criticisms of meta-analysis methodology, which is the tendency to use studies of poor quality (Glass et al., 1981). Therefore, the studies selected for this meta-analysis were evaluated by a threats-to-validity method (Hedges, 1986). This method provided a numerical rating of the degree to which a specific study design controlled for the seven threats to internal validity proposed by Cook and Campbell (1979). For each study, the degree of control of each of the seven threats to internal validity was rated on a 3-point Likert scale: 0 represented no control, 1 meant partial control, and 2 denoted full control of that threat.

Two raters were employed to rate the 50 studies collected. Due to time and financial constraints, one rater was requested to rate all 50 studies and the other rater rated only 39 of the 50 studies. Percentage agreement of the ratings on those 39 articles rated by both raters became the inter-rater reliability index used to reflect the reliability of this rating process. A one-hour training session was conducted for each rater. Definitions of each threat (Cook & Campbell, 1979) were presented to ensure standardised understanding of the construct of the seven threats.

For each threat, total agreement was observed in situations where the two raters assigned the same point to that threat. Minor disagreements were those situations where a difference of one point between the two ratings was observed; these were then resolved by taking the average of the two ratings. In situations where total disagreement appeared, i.e. a difference of two points in the two ratings, exploration of the reason was conducted. A third rater was then introduced for a final decision of the rating.

Studies included for further analysis were those that achieved an overall internal validity score, a summation of all the seven scores, of no less than 4. Also, they had to have obtained a score of no less than 1 in the control for 'history' and 'maturation'. These studies were then examined to see if they provided enough data for calculating treatment effect size. For the present meta-analysis, certain statistical data were essential for calculating treatment effect size, which included either means and standard deviations, results of test of significance (e.g. t-test and F-test), or level of significance. Those studies that did not have the necessary data for calculating effect size were excluded for further analysis.

Coding. Based on the model proposed by Stock (1994), information in the following seven categories was coded:

1. Identification
2. Research design

3. Sampling
4. Subject characteristics
5. Independent variable characteristics
6. Dependent variable characteristics
7. Statistical data for calculating the effect size

Two coders, different from the two raters employed for evaluating the internal validity of the studies, were responsible for coding all data sets that passed the data evaluation stage. Again, due to time and financial constraints, only 15 randomly selected studies were coded by both coders so as to yield an interrater reliability index, expressed as percentage of agreement of the two coders, reflecting the reliability of the coding process.

Validity. Validity of measurements in meta-analysis depends very much on the clarity of definitions, adequacy of reported information, and the degree of inference a coder must make in coding arbitrary information (Glass et al., 1981). To ensure a high degree of validity of measurements, definitions of specific terms, such as the seven threats to internal validity, were provided. Specific questions were clarified in the training session conducted for the two raters and the two coders involved in this process. Also, the coding form (Appendix 1) was pilot tested and revised five times to ensure its clarity before it was used in this project.

Reliability. The reliability of measurements can be a problem for meta-analysis if different coders judge characteristics of a study in different ways. In this project, reliability indices were represented by interrater reliability expressed as percentage agreement of 1) the two raters rating the degree of control of the seven threats to internal validity of each study, and 2) the two coders coding data other than the seven threats to internal validity from each study.

Using two different indices to reflect the reliability of the present analysis is considered to be more meaningful because some items, such as publication date (Index 2), should yield a much higher interrater agreement than other items, such as internal validity (Index 1) (Orwin, 1994). Therefore, using either one of the two interrater reliability indices could be misleading about the reliability of the present analysis. Because of the different expectation of the degree of agreement of the two indices, percentage agreement of 70% for Index 1 and 90% for Index 2 is considered to be satisfactory. Orwin (1994) commented that agreement across individual variables could range from 0.24 to 1.00.

Stage IV - Analysis

In the present meta-analysis, the fixed effects model (Hedges, 1994) is adopted to guide data analysis.

> In the fixed effects, or conditional, model, the universe to which generalizations are made consists of ensembles of studies identical to those in the study sample except for the particular people (or primary sampling units) that appear in the studies. (p.30)

Thus, inferences are limited to cases in which the ensemble of values of the predictor variables are represented in the sample.

In this meta-analysis, data analysis was conducted following the procedures suggested by Hedges and Olkin (1985). The process included effect sizes estimation, test of homogeneity of data set, and test of publication bias. The steps were detailed below.

Computer program Meta (MS-DOS version 5.0 by R. Schwarzer) was used for performing the analysis. Estimation of mean effect sizes and their respective 95% confidence intervals, test of homogeneity of data sets, and Fail-Safe N were calculated and reported. Accuracy of the computer program was verified by Cameron (1992). Furthermore, the obtained effect size estimates were compared with those reported by Terman et al. (1989b). Only very slight discrepancy was identified, which could be explained by rounding error.

Effect size estimation. As discussed in the previous chapter, effect size is a scale-free index of effect magnitude (Glass, 1976) developed from Cohen's (1969) concept of standardized mean difference. It is defined as the mean difference between experimental and control groups divided by within-group standard deviation (Glass et al., 1981). Hedges and Olkin (1985) later found that this effect size estimate had a small sample bias. It tended to overestimate population effect size, especially when sample sizes were small. Therefore, they employed some statistical procedures to remove the sample bias identified. They called this unbiased effect size estimator Index d, and called that bias effect size estimator suggested by Glass et al. (1981) Index g. There is in fact only a slight discrepancy between Indices g and d after the appropriate mathematical manipulation. The mathematical derivatives of Indices g and d are presented in Appendix 2.

In this meta-analysis, Indices g were obtained because they were required for calculating the pooled effect size of a group. They were calculated by first subtracting the post-test from the pre-test scores of the HDRS or the AS to obtain gain scores. These gain scores were then divided by the pooled standard deviations to give effect size Index g.

In a meta-analysis, the effect size often must be estimated from very limited information. As long as values of a test of significance (e.g t-test and F-test) or specific level of significance (i.e. p-value) were reported, effect size could be estimated following the mathematical procedures suggested by Hedges and Olkin (1985). In this meta-analytic review, two studies reported only unspecific p-values. In those situations, a conservative approach was adopted. If the reported significance level was that p was less than 0.05, effect size was constructed based on a p level equalled to 0.05. This method aimed at avoiding an overestimation of treatment effect size, and yet including as many studies as possible for further analysis. Three studies did not provide sufficient data for estimating their respective effect sizes. In view of the fact that effect sizes calculated by Meta, the computer program used in the present analysis, were very close to that published by Terman et al. (1989b), the effect sizes of those three studies published by Terman et al. were adopted in this meta-analysis.

In some instances multiple effect sizes were generated from the same sample of subjects in a study. For example, two values of effect size were generated from the same data set when it provided findings of a cross-over counter-balance method and a single group repeated measure method. Should both effect size estimates be processed for further analysis? Entering both effect sizes generated by the same sample of subjects for analysis has been one of the major criticisms of meta-analysis (Glass et al., 1981). Hedges and Olkin (1985) suggest that only one effect size estimate should be chosen from each study to satisfy the independence assumption of meta-analytic statistics. This suggestion is followed in the present meta-analytic review. Only one effect size from each sample of subjects was entered for further analysis. In situations where more than one effect size was generated, an average value, obtained by weighing each g index by the number of subjects on which it was based (Cameron, 1992), was entered into the pool for further analysis.

Estimation of the mean effect size of pooled data sets followed the weighted integration method (Hedges & Olkin, 1985). The method involved converting Index g to d. Then each Index d was weighted by the reciprocal of its variance. The mean effect size was obtained from the average of these weighted d, and the 95% confidence intervals were constructed.

The next step was to explore the relationships between mean effect sizes of different phototherapy parameters studied. Descriptively, the 95% confidence intervals of the mean effect sizes of different phototherapy parameters were compared to see if they overlapped. The absence of any overlap implied that these mean effect sizes were different.

Inferentially, an analysis of variance for effect sizes was conducted. In this regard, Glass et al. (1981) suggest the application of conventional statistical methods, such as multiple regression analysis and analysis of variance, for analyzing effect magnitude data in meta-analytic methodology. Hedges (1986) argues that such an application cannot be justified on either statistical or conceptual grounds. Statistically, conventional analysis fails to directly test the consistency of effect sizes across studies included in one pool and the test for treatment-by-study interactions is lacking. Conceptually, the non-equivalent sample sizes of studies in meta-analysis implies variation in error variances, which is a violation of the homoscedasticity assumption of conventional statistical methods. Fortunately recent developments in statistical methods for effect size analysis have overcome the technical problem of applying conventional inferential statistics in meta-analysis. The statistical procedures employed in the present meta-analysis are detailed by Hedges (1994, p.285-299).

Homogeneity. A population effect size can only be interpreted reliably if the underlying data set is sufficiently homogeneous. To examine the consistency of effect sizes across studies in a sample (homogeneity), the homogeneity statistic Q was employed. It is an asymptotic chi-square distribution with $k - 1$ degree of freedom (Hedges & Olkin, 1985). If the obtained value of Q exceeded the predetermined critical value of the chi-square distribution with $k - 1$ degrees of freedom, the null hypothesis of homogeneity of data sets was rejected. The critical level selected for this meta-analytic review was $p < 0.05$.

In situations where homogeneity was not achieved, outliers, estimates inconsistent with others in the pool (Hedges, 1987), were removed from analysis to see if that helped increase the homogeneity of the data sets. Hedges (1987) suggests that this is a common procedure in both the physical and social sciences. In this meta-analysis, outliers were identified through the Tukey's (1977) methods. Schematic box plot of the obtained effect size estimates was conducted. Data points that lay outside the inner fence were considered "outliers", and those that lay beyond the outer fence were considered "far outliers".

Publication Bias. This bias could be the result of missing data or the file-drawer syndrome discussed earlier. Although publication bias for studies on phototherapy for SAD was believed to be minimum, this publication bias error can have a strong negative impact on the validity of the findings of the present meta-analysis; therefore, the potential for bias needed to be addressed seriously.

In the present analysis, representativeness of the data, i.e. the degree of publication bias and the amount of missing data, was examined in two ways. The first was to construct funnel graphs, i.e. a plot of sample size versus effect size. If no publication bias were present, the plot should look like an inverted funnel, i.e. with the spout pointing upward (Begg, 1994). The rationale is that studies of small sample size produce highly variable effect size estimates, which by chance should be much farther from the true mean effect size than the aberrant values of studies of large sample size. In this analysis, funnel graphs were plotted only for the morning, evening, and morning-evening light groups using medium light intensity. Data from other groups were insufficient for the construction of funnel graphs.

The second method was to calculate and examine the Fail-Safe N (Rosenthal, 1979). This approach provides a direct assessment of the threat posed by sampling bias in the literature search (Orwin, 1983). It involves an estimation of the number of file-drawer studies, i.e. studies that produced insignificance findings, required to bring the mean effect size down to a defined critical level. In this meta-analysis, the formula used for the calculation was developed by Orwin (1983). Fail-Safe N was examined for the ‘light’ and ‘no light’ groups stated in Hypothesis 1. The nature of the other three hypotheses, stated above, would not render the application of this Fail-Safe N method for examination of publication bias.

VI. Results

Data collection commenced in April 1993 and ended August 1994. Relevant studies were collected, evaluated, screened, and coded for data analysis and hypothesis testing. The findings of the present meta-analytic review were categorised into four areas: description of the sample, validity, reliability, and hypothesis testing, and were presented as follows.

Description of the Sample

Size. After a thorough literature search, 46 relevant articles published from 1984 to 1994 were located and collected from the university libraries or inter-library loan service. Unpublished data were solicited through the use of a questionnaire (Appendix 3) mailed to 166 clinicians/researchers listed in Norman Rosenthal's (1993) book on SAD. Twenty-one responses were received. Seventeen of them replied that they did not have any unpublished data. The other four provided one unpublished data set each from their research projects in progress. In other words, none of these data sets was unpublished because of insignificant findings.

The present response rate from researchers and clinicians in the field, although low, was within the expectation of the author. The situation was comparable with that experienced by Hyde (1981), who tried to obtain missing information in 18 articles from the respective authors. Although all 18 authors were successfully located and contacted, only 7 responded, and only 2 provided the information that Hyde needed. As noted by Light and Pillemer (1984), the chance of success in soliciting information from the authors could be quite unpredictable.

The total number of articles collected for further analysis was 50; 46 of them were published and 4 were unpublished data sets. Compared to the sample size of 29 published and unpublished studies collected by Terman et al. (1989b) for secondary analysis, the present sample size is almost double that of Terman's study.

Single group repeated measures design was identified in all 50 articles. A few studies reported using the between-subject design with a control condition, which could be a dim light, an ion generator, or no light at all. Whether these conditions were true control conditions for studies of phototherapy for SAD was questionable. Therefore, effect sizes of these studies were estimated based on a within-subject repeated measures design, i.e. the experimental and the reported control groups were treated as two separate individual groups, and subjects in each group served as their own control.

The 50 published and unpublished data sets were then evaluated for inclusion in the sample. Four published articles were excluded after the internal validity evaluation procedure, and 5 published and 1 unpublished articles were excluded because of insufficient data for calculating treatment effect size.

Altogether 40 articles, 37 published (92.5%) and 3 unpublished (7.5%), were coded for analysis and hypothesis testing. Among the 40 acquired published studies, 36 (97.3%) were identified in refereed journals. Only one study (2.7%) was obtained from a chapter of a book. A list of the studies included in the present meta-analysis is presented in Appendix 4.

Characteristics. Sample characteristics were categorised into three areas:

1. the locations of the studies - countries of origin and setting of the studies
2. the control of extraneous variables - control for sleep/medications/other forms of therapy
3. the characteristics of the subjects making up the present sample pool - subject selection criteria, sampling techniques, subject assignment methods, gender composition and

mean age of the subjects, and the
distribution of subjects' diagnoses.

Locations of the studies were identified on four of the five continents of the world. These four continents were America, Asia, Australia, and Europe. As presented in Table 6.1 below, about 70% of the studies were from North America.

Table 6.1: Country of Origin of Studies

CONTINENT	COUNTRY	NO. OF STUDIES (%)
America	Canada	3 (7.5%)
	U.S.A.	25 (60 %)
	Canada/U.S.A. (Multi-centres)	1 (2.5%)
Asia	Japan	1 (2.5%)
	Russia	1 (2.5%)
Australia	Australia	1 (2.5%)
Europe	Iceland	1 (2.5%)
	Netherlands	1 (2.5%)
	Switzerland	3 (7.5%)
	United Kingdom	1 (2.5%)
MISSING DATA		3 (7.5%)
TOTAL		40 (100 %)

Only 32 of the 40 studies offered information regarding the cities of the respective research sites. Based on the reported information, the latitudes of the cities were obtained from Canadian Oxford World Atlas

(Stanford, 1992). Out of these 32 studies, only one was conducted in the southern hemisphere, in Australia. The remaining 31 studies were conducted in the northern hemisphere. Latitudes of these northern hemispheric cities spanned from 39 00 N to 64 50 N [median latitude was 45 32 N; mode latitude was 39 00 N]. Details of the cities and latitudes of the research sites are presented in Table 6.2 below.

Table 6.2: City of Origin of the Studies

CITY	LATITUDE	NO. OF STUDIES
Bethesda	39 00 N	6
Illinois	40 00 N	1
Philadelphia	40 00 N	3
New York	40 40 N	2
Rochester	43 07 N	1
Minnesota	44 00 N	1
East Lansing	45 00 N	1
Portland	45 32 N	1
Vancouver	45 38 N	2
Zurich	47 23 N	2
Basal	47 33 N	1
Seattle	47 35 N	4
London	51 30 N	1
Edmonton	51 37 N	1
Groningen	53 13 N	1
Novosibirsk	55 04 N	1
Reykjavik	64 09 N	1
Fairbanks	64 50 N	1
Melbourne	37 45 S	1
MISSING DATA		8
TOTAL		40

With respect to the setting of the sampled studies, i.e. the use of in-patient or out-patient population, 55 data sets were identified from the 40 studies (some studies reported findings on both in- and out-patient populations). Eight out of these 55 data sets (14.5%) reported findings of in-patient populations. Twenty-seven of them (49.1%) recruited out patients in their studies. Six data sets (10.9%) were based on a combination of in- and out-patient populations. Finally, 14 of these 55 data sets (25.5%) did not specify the setting of their studies.

Control for sleep was reported in 18 (42.5%) of the 40 studies selected. The others (57.5%) did not specify whether such a control was implemented. Among those 18 studies which reported the regulation of subjects' sleeping schedule, only 13 studies specified the wake-up time for their subjects, 9 (69.2%) of them required their subjects to get up at 0600 hour, 3 (23.1%) of them required their subjects to get up at 0700 hour, and 1 (7.7%) of these 13 studies set the wake-up time at 0800 hour.

Control for medications was examined. Only 23 of the 40 studies provided data on this aspect. Out of these 23 studies, 19 (82.6%) required their subjects to be medication free. The others (17.4%) reported no control for the use of medications by their subjects.

The majority of the studies (95%) did not report whether control for other forms of therapy, e.g. psychotherapy, was exerted while their subjects underwent light treatment. If other forms of therapy were used prior to/during the course of phototherapy, treatment efficacy of light could be seriously confounded. The forms of therapy used can be a significant third variable in phototherapy studies for SAD.

Sample selection criteria were reported in 37 of the 40 studies selected. Among these 37 studies, 20 (43.2%) used the criteria established by Rosenthal et al. (1984, p.72), which specified that people to be diagnosed as SAD had to have:

1) a history of major affective disorder, according to the Research Diagnostic Criteria (RDC) (Spitzer, Endicott, & Robins, 1978)
2) at least two consecutive years in which depression had developed during the fall or winter and remitted during the following spring or summer
3) residence close enough for maintaining adequate communication.

Eight studies (21.6%) specified that potential subjects needed to suffer from a seasonal pattern of affective disorder, and the diagnosis of the affective disorder had to follow that specified in the RDC (Spitzer et al., 1978). Four studies (10.8%) followed the criteria for SAD set in the *Diagnostic and statistical manual of mental disorders* (DSM), the third edition or its revised version (American Psychiatric Association, 1980, 1987).

The remaining 9 studies (24.3%) used a combination of different criteria. Five of them (13.5%) used a combination of Rosenthal and DSM criteria, and the other four (10.8%) used a combination of Rosenthal, DSM, and Feighner (Feighner et al., 1972) criteria for determining who should be included in their studies.

Difficulty in identifying and accessing the SAD population rendered random sampling technique impossible. Recruitment of subjects of all 40 studies relied mainly on volunteers or referrals from local psychiatrists, therapists, and/or clinics. Even though random sampling was not used by these studies, the strategy of random subject assignment to different treatment groups was employed by 24 (68.6%) of the 35 studies which reported their subject assignment procedures. Three studies (8.6%) used the matched pair method, and the other eight studies (22.9%) assigned subjects to different treatment groups non-randomly.

Altogether 1129 subjects were included in the sample pool of the present meta-analysis. Gender composition, mean age, and the distribution of diagnoses were not reported in all of the 40 studies. Among those which reported the gender distribution of their subjects (n=667), the ratio of females (520) to males (147) was 3.54:1. The mean age ranged from 28.7 to 47 years old, with the median mean age of 38.3 years old. The distribution of different affective disorder diagnoses was reported for 208 subjects. According to the RDC (Spitzer et al., 1978), 97 (46.6%) were diagnosed as suffering from unipolar affective disorder, 97 (46.6%) had bipolar II affective disorder, and 14 (6.7%) were diagnosed as having bipolar I affective disorder.

Validity

Two measures to evaluate the effect of publication bias and missing data, hampering the validity of the present findings, were employed. The first one was the use of funnel graphs, and the second one was the estimation of the Fail-Safe N.

Four funnel graphs were constructed and are presented in Figures 6.1 to 6.4 below.

Figure 6.1: Morning light of medium intensity (HDRS)

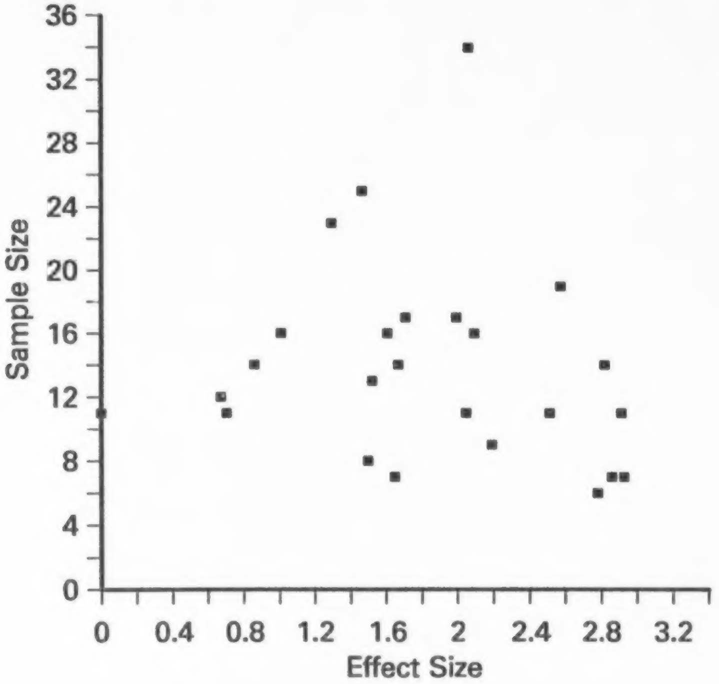


Figure 6.2: Evening light of medium intensity (HDRS)

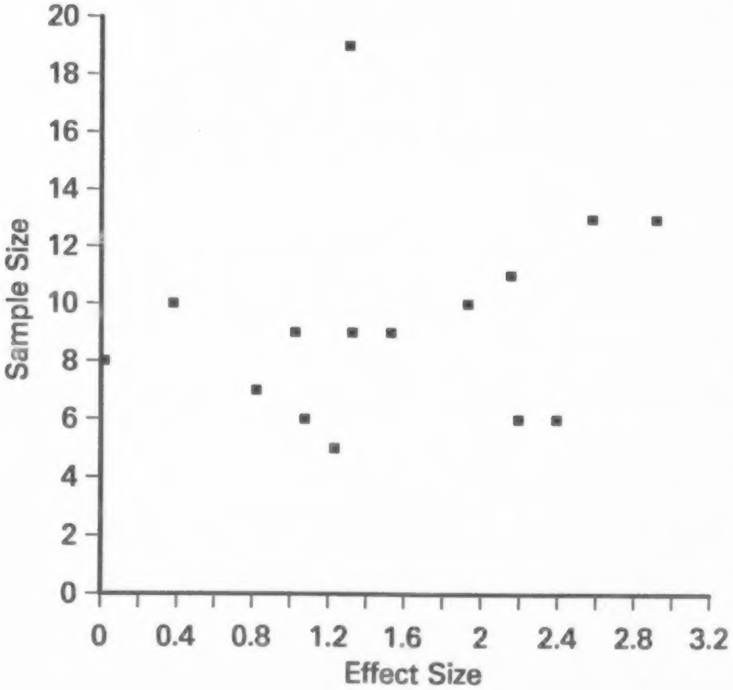


Figure 6.3:Morning-Evening light of medium intensity (HDRS)

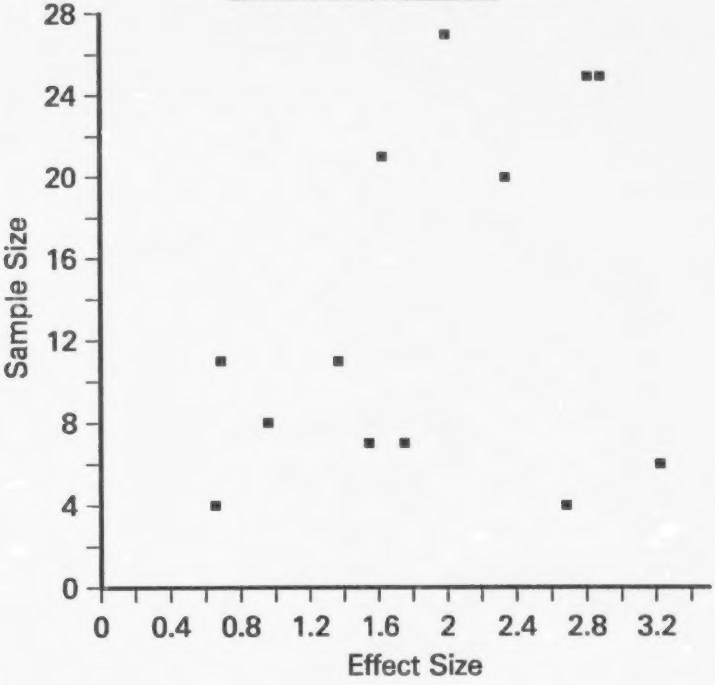
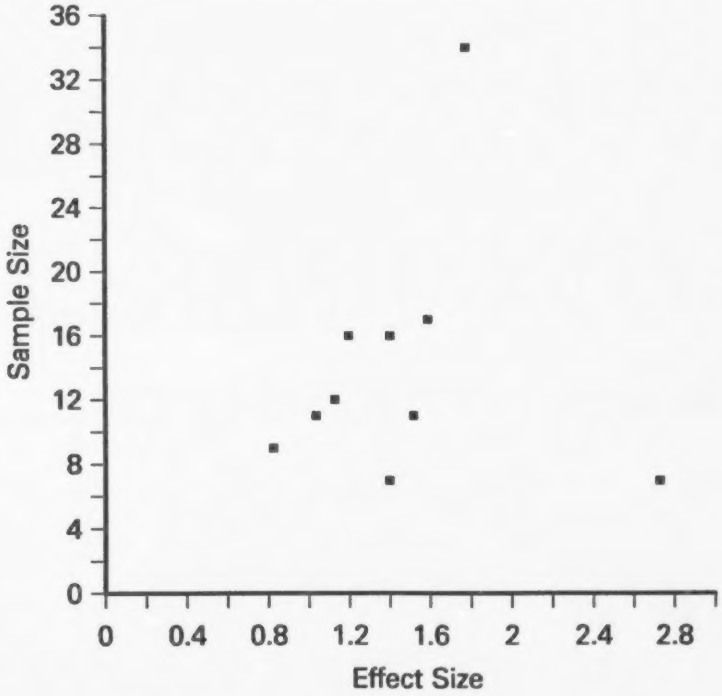


Figure 6.4:Morning light of medium intensity (AS)



The shapes of the above four funnel graphs are like an inverted funnel with the spout pointing upward. This observation suggests that the validity of the present data is not threatened by serious publication bias. This also provides reassuring evidence for the author's initial proposal that publication bias is not a serious concern for the present meta-analysis.

With respect to the Fail-Safe N value, about 150 phototherapy studies of insignificant findings would be required to pull the mean effect size of the light group from 1.38 down to 0.5, which was the estimated mean effect size of the no light group. It seems highly unlikely that there are 150 unpublished studies, all of which contain insignificant findings, stored in file drawers somewhere. Therefore, the result of the Fail-Safe N analysis lends further support to the author's initial proposal that publication bias is not a serious concern for the present meta-analysis.

Reliability

Two interrater reliability indices, expressed as percentage agreement between the two raters or coders, were obtained. One index represented the percentage agreement of the rating on the degree of control for the seven threats to internal validity on the 39 studies rated by both raters. The second index was expressed as the percentage agreement of the coding decisions, other than threats to internal validity, on the 15 randomly selected studies coded by both coders.

Index 1: Internal validity rating. The percentage agreement of the raters on each of the seven threats to internal validity on the 39 studies is presented in Tables 6.3 to 6.9 (N =39).

Table 6.3: Agreement of raters' rating on History

		Rater A		
		2	1	0
Rater B	2	9	2	6
	1	2	10	0
	0	0	2	8

Total Agreement (%) = 69.2%
Minor Disagreement (%) = 15.4%
Total Disagreement (%) = 15.4%

Table 6.4: Agreement of raters' rating on Instrumentation

		Rater A		
		2	1	0
Rater B	2	21	8	2
	1	0	8	0
	0	0	0	0

Total Agreement (%) = 74.4%
Minor Disagreement (%) = 20.5%
Total Disagreement (%) = 5.1%

Table 6.5: Agreement of raters' rating on Statistical Regression

		Rater A		
		2	1	0
Rater B	2	0	0	0
	1	2	27	7
	0	0	0	3

Total Agreement (%) = 76.9%
Minor Disagreement (%) = 23.1%
Total Disagreement (%) = 0%

Table 6.6: Agreement of raters' rating on Maturation

		Rater A		
		2	1	0
	2	24	2	0
Rater B	1	2	4	0
	0	3	0	4

Total Agreement (%) = 82.1%
Minor Disagreement (%) = 10.2%
Total Disagreement (%) = 7.7%

Table 6.7: Agreement of raters' rating on Attrition

		Rater A		
		2	1	0
	2	12	0	1
Rater B	1	1	15	2
	0	1	2	5

Total Agreement (%) = 82.1%
Minor Disagreement (%) = 12.8%
Total Disagreement (%) = 5.1%

Table 6.8: Agreement of raters' rating on Selection

		Rater A		
		2	1	0
Rater B	2	16	0	0
	1	3	9	2
	0	1	2	6

Total Agreement (%) = 79.5%
Minor Disagreement (%) = 17.9%
Total Disagreement (%) = 2.6%

Table 6.9: Agreement of raters' rating on Testing

		Rater A		
		2	1	0
Rater B	2	0	0	0
	1	3	32	2
	0	0	1	1

Total Agreement (%) = 84.6%
Minor Disagreement (%) = 15.4%
Total Disagreement (%) = 0%

As presented above, percentage of total agreement on each of the 7 threats ranged from about 70% to 85%, which was considered satisfactory according to the criterion set for this meta-analysis.

Index 2: Coding of other data. On all items of the 15 articles coded by both raters, the overall percentage agreement of their rating was about 98%. Further exploration of the 2% disagreement of the rating of the two raters showed that their trivial discrepancy was due to mis-reading and mis-coding of information by either one of the two coders. Those mistakes were then corrected after double checking the information contained in the original articles.

Hypothesis Testing

Multiple analyses were conducted to verify the three a priori hypotheses specified in the previous chapter. The meaning of some abbreviations used is given in Table 6.10 below:

Table 6.10: Meanings of notations

Abbreviation	Meaning
k	Number of effect sizes
N	Sum of number of subjects in all studies
Mean weighted d	Mean weighted effect sizes (weighted by sample sizes)
C.I.	Confidence interval
Q	Homogeneity statistic for mean effect sizes
*	Significance indicates rejection of the hypothesis of homogeneity at $p < 0.05$
Negative effect size	Increase in severity of symptoms of SAD

In each analysis, outliers were gradually removed by the Tukey's (1977) procedure so as to attain the homogeneity requirement at a p-level of 0.05 or greater. An examination of Tables 6.11 to 6.17 indicates that this procedure did not drastically alter mean effect sizes in most analyses.

The only exception was that of the strong morning light group (Table 6.12). The significant difference in mean effect size after outliers were removed could be due to the width of its range as well as the skewed distribution of the effect sizes. An examination of the its two outliers showed that one used the lowest end (7000 lux) of strong light intensity (Eastman et al., 1992), and the other one did not implement a tight control for the timing of morning light administration (Blashko et al, p.c.).

Frequency distributions of effect sizes are shown in Figures 6.5 and 6.6 below. A list showing the studies included in each analysis is presented in Appendix 5.

Figure 6.5: Frequency Distribution of effect sizes measures by HDRS

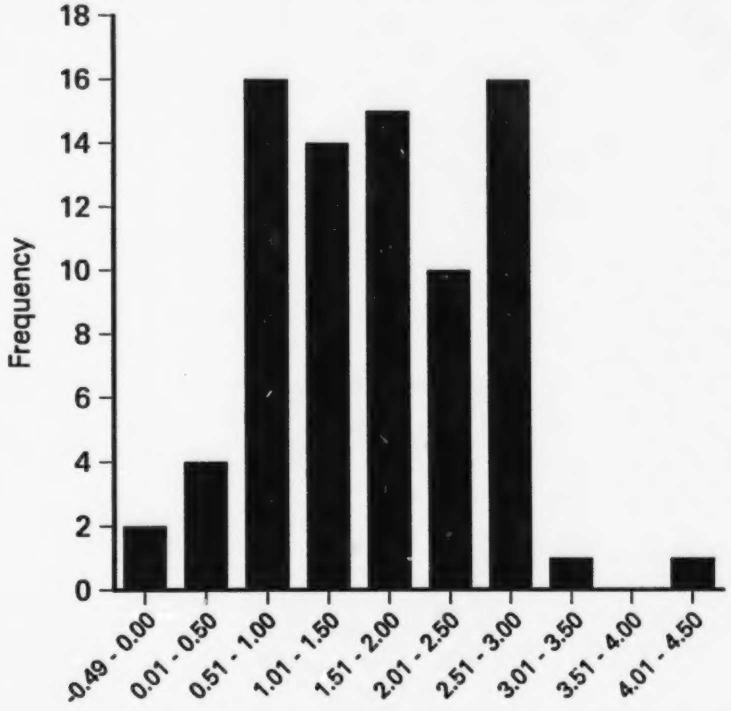
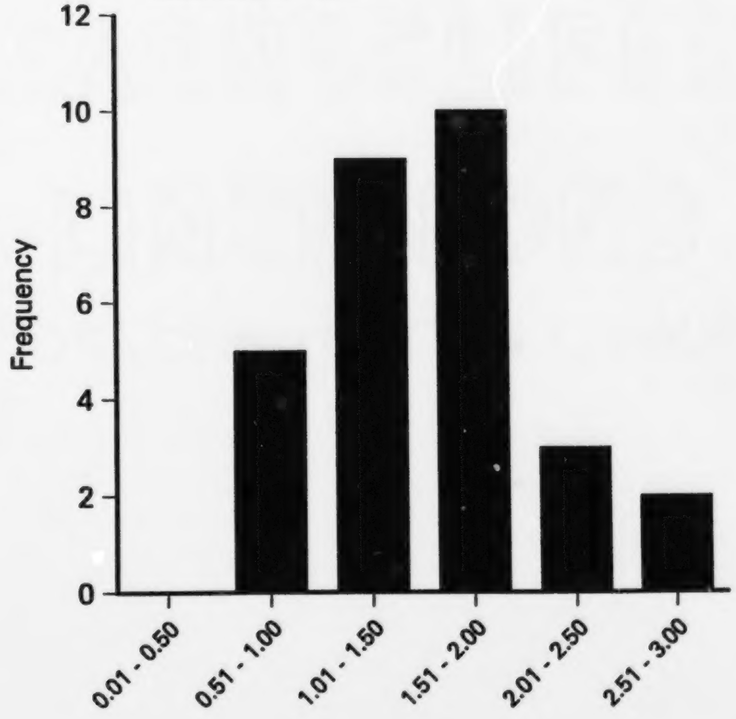


Figure 6.6: Frequency Distribution of effect sizes measures by AS



Hypothesis 1: Light is effective in alleviating symptoms of SAD. Seventy-six data sets were included in the phototherapy group (Light) and 3 data sets were included in the no light control group (No Light). Their respective population effect sizes, measured by the HDRS, were estimated. The range of effect sizes for the Light Group was -0.22 to 4.28, and that for the No Light Group was 0.12 to 0.89. The results are presented in Table 6.11 below.

Table 6.11: Overall effect of phototherapy

Variable	K	N	Mean weighted d	95%C.I.for d	Q
Light	76	1058	1.38	1.28 to 1.48	247.05*
No Light	3	71	0.53	0.19 to 0.86	3.99

As noted in Table 6.11 above, the 95% C.I. of the two groups did not overlap, suggesting that the antidepressant effects of the Light and No Light groups were different. The results showed that phototherapy was more effective than the no light control in alleviating SAD as measured by the HDRS.

To further confirm this observation, test of significance procedures using a chi-square distribution, suggested by Hedges (1994, p.292), was conducted to compare the difference in the mean effect sizes between the Light and the No Light Groups. The results of such a test confirmed the above stated observation and showed that the mean effect size of the Light Group was significantly larger than that of the No Light Group (Chi-Square value = 23.04, df=1, p<0.01). Hypothesis 1 was confirmed.

The light group was observed to be significantly heterogeneous. Studies were then clustered according to those moderator variables, i.e. intensity, time of light administration, and spectrum of light used, identified based on the literature review.

Hypothesis 2: Light intensity varies positively with the treatment effect size. Three separate analyses were conducted to verify this hypothesis.

The first one compared the treatment effect of strong (range of effect sizes = 0.94 to 4.28), medium (range of effect sizes = 0.00 to 2.92), and dim (range of effect sizes = -0.22 to 2.52) light intensity, measured by the HDRS, within the morning light group. The results were as follows:

Table 6.12: Effect of morning phototherapy of different intensities measured by the HDRS

Variable (lux)	K	N	Mean weighted d	95%C.I.for d	Q
Dim (/=600)	8	167	1.05	0.82 to 1.29	41.29*
	7	154	0.98	0.74 to 1.22	33.85*
	6	132	1.23	0.96 to 1.50	14.69*
	4	94	**1.11**	**0.80 to 1.42**	7.58
Medium (1700 to 3500)	25	360	1.50	1.33 to 1.67	71.53*
	23	326	1.69	1.51 to 1.87	37.47*
	22	315	**1.74**	**1.56 to 1.93**	31.64
Strong (6000 to 10000)	5	108	1.64	1.32 to 1.96	24.68*
	3	71	2.06	1.65 to 2.48	8.79*
	3	40	**2.94**	**2.30 to 3.58**	0.8

After the removal of respective outliers, the 95% C.I. of the estimated effect size of the three groups did not overlap with each other, suggesting that the effect of phototherapy did vary with the intensity of light used. The stronger the light intensity, the stronger the antidepressant effect of phototherapy.

Analysis of variance procedures following a fixed effect model, suggested by Hedges (1994, p.285-299), was conducted to compare the difference in the mean weighted d of the three groups of different light intensity. The results of this modified ANOVA further confirmed the above stated observation. The mean effect sizes of the three groups were significantly different from each other (Chi-square value = 23.70, df=2, $p<0.05$). Strong light was more effective than medium light (Chi-square value = 5.95, df=1, $p<0.05$) and dim light (Chi-square value = 21.83, df=1, p<0.05). Medium light was also more effective than dim light in treating SAD (Chi-square value = 13.65, df=1, p<0.05). Hypothesis 2 was confirmed.

The second comparison was conducted on the treatment effect of strong (range of effect sizes = 1.14 to 2.18), medium (range of effect sizes = 0.83 to 2.73), and dim (range of effect sizes = 0.63 to 2,.38) light intensity, measured by the AS, within the morning light group.

Table 6.13: Effect of morning phototherapy of different intensities measured by the AS

Variable (lux)	K	N	Mean weighted d	95%C.I.for d	Q
Dim (</=600)	6	140	1.31	1.05 to 1.57	14.08*
	4	116	**1.32**	**1.03 to 1.60**	7.55
Medium (1700 to 3500)	10	140	**1.41**	**1.15 to 1.68**	6.92
Strong (6000 to 10000	3	79	**1.29**	**0.94 to 1.63**	2.70

Significant overlap of the 95% C.I. of the estimated effect sizes of the three groups, after the removal of outliers, was observed. This made it unclear whether one condition was more effective than another in terms of alleviating the atypical symptoms of SAD. Analysis of variance procedures following a fixed effect model, suggested by Hedges (1994, p.285-299), was then conducted to verify whether the three mean weighted d were different significantly. The results of this modified ANOVA showed no statistically significant difference among the three mean effect sizes (Chi-square value = 0.3615, df=2, p>0.05), suggesting that the relationship between light intensity and alleviation of atypical symptoms of SAD was insignificant.

The third analysis compared the treatment effect of dim and medium light intensity, measured by the HDRS, in the morning-evening light group. Their respective ranges of effect sizes were 0.56 to 1.43 for dim light and 0.66 to 3.22 for medium light. The results are presented in Table 6.14.

Table 6.14: Effect of morning-evening phototherapy of different intensities measured by the HDRS

Variable (lux)	K	N	Mean weighted d	95%C.I.for d	Q
Dim (</=600)	5	56	**0.60**	**0.22 to 0.97**	1.2
Medium (1700 to 3500)	13	126	1.84	1.60 to 2.09	31.1*
	11	161	2.01	1.74 to 2.28	19.18*
	10	153	**2.09**	**1.81 to 2.38**	14.38

As noted in Table 6.14, the 95% C.I. of the estimated effect sizes of the two groups, after the removal of respective outliers, did not overlap with each other. The findings suggested that medium light was more effective than dim light in alleviating the symptoms of SAD.

To further confirm this observation, test of significance procedures using a chi-square distribution, suggested by Hedges (1994, p.292), was conducted to compare the difference in the mean effect sizes between the two groups. The results of such a test confirmed the above stated observation and showed that medium light produced a significantly larger effect size than dim light (Chi-Square value = 39.75, df=1, $p<0.05$). Hypothesis 2 was confirmed in this analysis.

Hypothesis 3: Morning light is a more effective treatment regime than light administered at any other times of the day. Three separate analyses were conducted to verify this hypothesis. The first one compared treatment efficacy of medium light, measured by the HDRS, of the morning (range of effect sizes = 0.00 to 2.92), midday (range of effect sizes = 1.06 to 2.44), evening (range of effect sizes = 0.02 to 2.92), and morning-evening (range of effect sizes = 0.66 to 3.22) light groups.

Table 6.15: Effect of medium light phototherapy administered at different times of day measured by the HDRS

Variable	K	N	Mean weighted d	95%C.I.for d	Q
Morning	25	360	1.50	1.33 to 1.67	71.53*
	23	326	1.69	1.51 to 1.87	37.47*
	22	315	**1.74**	**1.56 to 1.93**	31.64
Midday	4	41	**1.27**	**0.79 to 1.75**	1.77
Evening	15	141	1.33	1.06 to 1.60	30.92*
	13	120	**1.35**	**1.06 to 1.64**	16.69
Morning-Evening	13	126	1.84	1.60 to 2.09	31.1*
	11	161	2.01	1.74 to 2.28	19.18*
	10	153	**2.09**	**1.81 to 2.38**	14.38

The morning-evening light group appeared to yield the best result among the four groups. Nevertheless, the existence of some overlap of the 95% C.I. of the estimated effect sizes of the four groups made their relationships difficult to depict.

Analysis of variance procedures following a fixed effect model, suggested by Hedges (1994, p.285-299), was conducted to compare the difference in variance of the mean weighted d of the four groups. The results of this modified ANOVA showed a significant difference in treatment efficacy among the four groups (Chi-square value = 15.09, df=3, $p<0.05$). Confirmed with the observation stated above, morning-evening light was more effective than morning light (Chi-square value = 4.66, df=1, $p<0.05$), midday light (Chi-square value = 8.03, df=1, $p<0.05$), and evening light (Chi-square value = 12.05, df=1, p<0.05). There was no statistically significant difference in treatment efficacy between the morning and midday groups (Chi-square value = 2.71, df=1, p>0.05), morning and evening light groups (Chi-square value = 3.81, df=1, p>0.05), and midday and evening light groups (Chi-square value = 0.10, df=1, p>0.05).

The second analysis involved the morning, the evening, and the morning-evening groups. Treatment efficacy of medium light of these groups, measured by the AS, was compared to identify the importance of timing of phototherapy administration. The ranges of effect sizes were 0.83 to 2.73 for the morning, 0.68 to 1.98 for the evening, and 1.50 to 2.61 for the morning-evening light groups.

Table 6.16: Effect of medium light phototherapy administered at different times of day measured by the AS

Variable	K	N	Mean weighted d	95%C.I.for d	Q
Morning	10	140	**1.41**	**1.15 to 1.68**	6.92
Evening	5	45	**1.13**	**0.68 to 1.59**	5.13
Morning-Evening	6 5	98 85	1.97 **2.06**	1.62 to 2.31 **1.68 to 2.44**	8.28* 6.83

Morning-evening light appeared to be most effective for treating the atypical symptoms of SAD. Also, morning light seemed to produce a larger treatment effect size than evening light, but this suggestion was confused by a significant overlap of the 95% C.I. of their estimated effect sizes.

Analysis of variance procedures following a fixed effect model, suggested by Hedges (1994, p.285-299), was conducted. The findings showed a significant difference in treatment efficacy among the three groups (Chi-square value = 11.21, df=2, $p<0.05$). The morning-evening light was significantly more effective than morning (Chi-square value = 8.12, df=1, $p<0.05$) and evening (Chi-square value = 8.93, df=1, $p<0.05$) light groups. Nonetheless, there was no statistically significant difference in treatment effect size between the morning and the evening light groups (Chi-square value = 0.74, df=1, $p>0.05$).

The third analysis involved those studies using dim light intensity in the morning and the morning-evening light groups. Treatment efficacy of these two groups, measured by the HDRS, was compared. Ranges of treatment effect sizes were -0.22 to 2.52 for the morning dim light and 0.56 to 1.43 for the morning-evening dim light groups. The results of the analysis are presented in Table 6.17.

Table 6.17: Effect of dim light phototherapy administered at different times of day measured by the HDRS

Variable	K	N	Mean weighted d	95%C.I.for d	Q
Morning	8	167	1.05	0.82 to 1.29	41.29*
	7	154	0.98	0.74 to 1.22	33.85*
	6	132	1.23	0.96 to 1.50	14.69*
	4	94	1.11	0.80 to 1.42	7.58
Morning-Evening	5	56	0.60	0.22 to 0.97	1.2

As noted in Table 6.17, morning dim light appeared to be more effective than morning-evening dim light, but their 95% C.I. of the two groups overlapped, making their relationship difficult to depict clearly. Therefore, a test of significance procedures using chi-square distribution, suggested by Hedges (1994, p.292), was conducted to compare the difference in the mean effect sizes between the two groups. The results of that test confirmed the postulation that morning dim light produced a significantly larger effect size than morning-evening dim light (Chi-Square value = 12.77, df=1, p<0.05).

Hypothesis 3 was only confirmed in the third analysis. It was rejected in the first and second analyses.

Conclusion. The findings of the present meta-analysis show that light is indeed effective in treating SAD. Light intensity is found to vary positively with the antidepressant effect for typical but not for atypical symptoms of SAD. Timing of phototherapy is insignificant for the therapeutic effect of light, and phototherapy in both morning and evening is more therapeutic than a single pulse of light administered at other times of day. The implications of these results will be discussed in the next chapter.

VII. Discussion

Seasonal affective disorder has been actively studied recently. Issues about SAD and phototherapy have been examined, but findings about the etiology of SAD and the optimum parameters of phototherapy are contentious. Conflicting inferences are drawn from findings of studies of small sample sizes, which makes it hard to judge the validity of each claim. The aim of the present project is to identify the consensus underlying these conflicting findings. Identification of effective treatment for SAD is an important clinical, public health, and educational issue. Not only patients with SAD will benefit by this discovery, but also those vulnerable adults and school-age children whose daily functioning at work or in school are compromised by symptoms of a mild seasonal affective condition.

A meta-analytic methodology was employed. Data from 40 published and unpublished articles were pooled to give a better depiction of the antidepressant effect of different parameters of light. Issues about the reliability of the process and threats to the validity of the conclusions, mainly due to publication bias and missing data, were examined. The value of the two interrater reliability indices obtained, 70% to 85% for

Index 1 (threats to internal validity) and 98% for Index 2 (descriptive and inferential data), suggested that the reliability of the data coding process was at an acceptable level according to the criterion set for this project.

The issue of validity of the conclusions could be a concern. Although publication bias should not exert too much influence on the present meta-analysis, as previously discussed, chances are that there are still some data missing, despite the effort invested by the author for collecting all relevant studies for the present meta-analysis. Fortunately, the results of the funnel graph plots and the Fail-Safe N provide reassuring evidence that the validity of the findings of the present meta-analysis is not at stake.

SAD Population Characteristics

Data obtained from 1129 subjects reported in the 40 articles included in the present meta-analysis were examined. Characteristics of the SAD population were estimated from the available data. The ratio of females to males SAD patients was estimated to be about 3.5 to 1. The mean age ranged from 28.7 to 47 years, with the median mean age of 38.3 years. Major diagnoses received by the SAD patients were bipolar II and unipolar affective disorders, according to the RDC criteria.

Bipolar I affective disorder was less frequently observed. These descriptive findings were compared with other reports of characteristics of the SAD population (Boyce & Parker, 1988; Hellekson, 1989; Rosenthal et al., 1984; Takahashi et al., 1991; Terman et al., 1989c; Thompson & Issacs, 1988; Wirz-Justice et al., 1989). Although discrepancy in the absolute value was observed, similarity in the patterns of findings, such as predominance of females in the SAD population, mean age at about 30 to 40 years old, and bipolar II and unipolar affected disorder being the major diagnoses, were noted. The discrepancy was interpreted as the consequence of sampling error.

Efficacy of Phototherapy

The point at issue is whether light carries any antidepressant effect for SAD. The findings of the present meta-analysis show that the mean effect size of phototherapy (d=1.38; 95%C.I.=1.28 to 1.48) is significantly larger than that of the no light control condition (d=0.53; 95%C.I.=0.19 to 0.86). This result confirms other studies (Rosenthal et al., 1989) that reported the antidepressant effect of light. It is worth noting that the mean effect size of phototherapy is estimated from a heterogeneous sample, as denoted by the value of the homogeneity Q value (247.05);

nonetheless, due to the fact that the heterogeneity of the sample should deflate rather than inflate the estimated population effect size, as heterogeneity tended to bring about a more significant cancellation effect of different estimated mean effect sizes, the presently reported estimated effect size of the phototherapy group should be more conservative than its true value. This, therefore, provides reassuring evidence that light did work to help alleviate symptoms of SAD.

The next question becomes: what are the optimum parameters of phototherapy for SAD. Treatment effect of different light intensities and time of light therapy administration were examined.

Dose-response relation. Dose is defined as the total amount of radiation delivered (Bielski et al., 1992) and can be expressed in terms of intensity and duration (Rosenthal & Wehr, 1987). Since the variation of the reported duration of phototherapy across studies followed a relatively stable pattern, as discussed in Chapter 3, intensity of light was used to reflect the dose of light used in therapy in this meta-analysis. The present findings are compared with studies directly or indirectly examining the dose-response relationship using duration and/or intensities as the independent variable(s).

With respect to the treatment efficacy of different light intensities, three analyses were conducted. The first two compared the treatment effect of dim, medium, and strong light intensity of the morning phototherapy group, measured by the HDRS and the AS. The last analysis compared the different treatment effect of dim and medium light intensity of the morning-evening phototherapy group measured by the HDRS. Tables 7.1 to 7.3 as well as Figures 7.1 and 7.2 summarise the findings.

Table 7.1: Treatment effectiveness of morning phototherapy of varying intensities measured by the HDRS

Group	Effect size (d)	95% C.I.
Dim	1.11	0.80 to 1.42
Medium	1.74	1.56 to 1.93
Strong	2.94	2.30 to 3.58

Dim light : </= 600 lux
Medium Light : 1700 to 3500 lux
Strong Light : 6000 to 10000 lux

Figure 7.1: Treatment effect size (HDRS) of morning light vs. light intensity

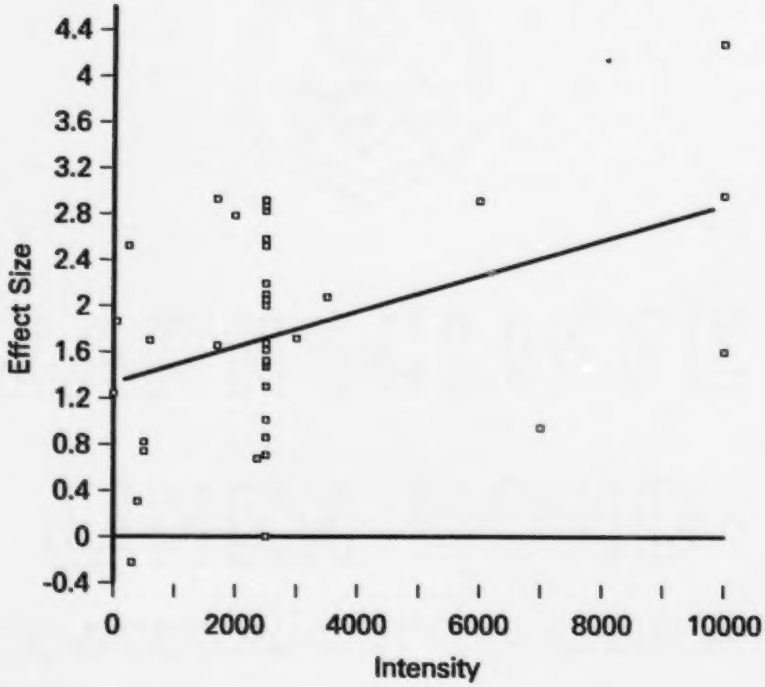


Table 7.2: Treatment effectiveness of morning phototherapy of varying intensities measured by the AS

Group	Effect size (d)	95% C.I.
Dim	1.32	1.03 to 1.60
Medium	1.41	1.15 to 1.68
Strong	1.29	0.94 to 1.63

Dim light : </= 600 lux
Medium Light : 1700 to 3500 lux
Strong Light : 6000 to 10000 lux

Figure 7.2: Treatment effect size (AS) of morning light vs. light intensity

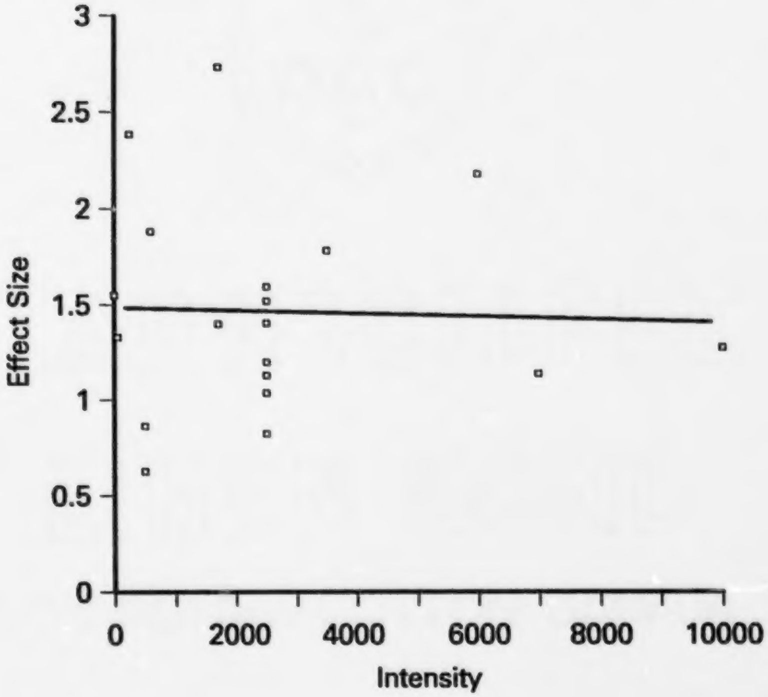


Table 7.3: Treatment effectiveness of morning-evening phototherapy of varying intensities measured by the HDRS

Group	Effect size (d)	95% C.I.
Dim	0.60	0.22 to 0.97
Medium	2.09	1.81 to 2.38

Dim light : </= 600 lux
Medium Light : 1700 to 3500 lux

An examination of these data indicated that while the first and third analyses, which compared treatment effect measured by the HDRS, gave confirmative evidence of the hypothesis that light intensity and the degree of antidepressant effect carried a positive relationship, the second analysis using the AS as the measuring tool for the antidepressant effect of light did not support this hypothesis. A plausible explanation of this phenomenon was that strong light was indeed more effective than weak light in controlling the typical symptoms of a depression, measured by HDRS, but not the atypical symptoms characterising SAD, measured by the AS.

Based on the above proposal, the convergency/divergency of the present findings with those of Wirz-Justice et al. (1987) and Terman et al. (1989a), using duration to reflect the dose of light therapy, can be explained. In Wirz-Justice et al.'s study (1987), a positive relationship between dose and treatment efficacy was observed. An examination of the methodology showed that only the HDRS was used to ascertain the value of the dependent variable.

In Terman et al.'s (1989a) study, both the HDRS and the AS were used as the measuring tools. Nonetheless, the frequency distributions that supported their proposed dose-response relation were in fact expressed as the combined scores of the HDRS and the AS. If dose related positively to the HDRS score but did not have any relationship with the AS score, the combined score should still show a positive correlation with the dose of light.

Rosenthal et al. (1984, 1985) studied the treatment efficacy of strong and dim light. They used the HDRS as the measuring tool and observed a relatively stronger antidepressant effect of the strong light, which is consistent with the present findings. Terman et al. (1989b) concluded a dose-response relation in their meta-analysis, such that strong light was more effective than dim light for SAD. Again, only the scores on the HDRS were examined in their meta-analysis.

Contrary to the above proposal, Lam et al. (1991c) employed the HDRS and the AS in their study and reported that strong light was more effective than dim light in alleviating the typical and atypical depression symptoms measured by the HDRS and the AS. Nonetheless, spectrum of light was included as another independent variable in their study, which made the proposed dose-response relation less easy to decipher.

Wirz-Justice et al. (1986) reported that bright (2500 lux) and dim (300 lux) light were equally effective as measured by the HDRS. Also, bright light was more effective, measured by the AS, in treating the SAD subjects that they studied. Again, different light spectra were used for the bright and dim light groups. Also, the only clinical criterion for the judgement of treatment effectiveness, employed in their study, was a change of the HDRS of more than 5 points. The findings thus obtained were likely contaminated by the initial difference in the severity of the condition as well as an unequal number of subjects in each group. In fact, an examination of the effect size of the bright white light and the dim yellow light showed that the former (d=2.72) produced a much larger effect size than the latter (d=1.22). The same argument could be applied to their reported effectiveness of the bright vs. dim light as measured by the AS.

A multicenter study (Joffe et al., 1993) reported similar antidepressant efficacy of light of 60 lux, 600 lux, and 3500 lux emitted from a light visor. The difference in light source, light box versus light visor, may explain the reported efficacy of dim light. Similar observations were reported by Rosenthal et al. (1993) in their multicenter study of the light visor for SAD, which found no evidence that the brighter visor (6000 lux) was more effective than the dim visor (400 lux).

A possible explanation of the discrepancy of Joffe et al. and Rosenthal et al.'s results with the present findings may relate to the use of light visor in their studies. The farther the light source from the eye, the less chance for the photon to hit the retina due to possible decreased frequency of eye glancing directly at the light source. Therefore, based on this theory, the light visor should have a superior antidepressant effect to the light box due to the proximity of the light source to the user.

Effect of dim light is likely a placebo effect. If it were not, the lack of any significant difference in the treatment efficacy of strong and dim light emitted from a light visor would suggest that photons provided by a dose of 60 lux might be sufficient to saturate the equilibrium of the unknown photochemical reactions underlying the antidepressant effect of light for SAD. This implies that light of lower intensity than expected may be adequate for triggering the photochemical reactions for treating SAD, provided that sufficient photons are absorbed by the user. In fact, Brainard et al. (1988) showed that light as weak as 29 lux could suppress melatonin production in normal human volunteers. Further research is required to substantiate this speculation and to verify whether a light visor is in fact a more superior light source than a light box.

Timing of phototherapy. Optimum timing of light administration has long been a contentious issue. As discussed in Chapter 2, different hypothesized pathophysiological mechanisms of SAD suggest a different optimum timing of phototherapy for SAD.

In this meta-analysis, three separate analyses were conducted to identify the optimum timing of phototherapy for SAD. The first two involved the comparison of different treatment effects of medium intensity light administered at different times of day, measured by the HDRS and the AS respectively. The third analysis was to compare the treatment efficacy between dim light administered in the morning and in the morning-evening treatment regimes. Tables 7.4 to 7.6 summarise the findings.

Table 7.4: Treatment effectiveness of medium light intensity light therapy administered at different times as measured by the HDRS

Group	Effect size (d)	95% C.I.
Morning	1.74	1.56 to 1.93
Midday	1.27	0.79 to 1.75
Evening	1.35	1.06 to 1.64
Morning-Evening	2.09	1.81 to 2.38

Table 7.5: Treatment effectiveness of medium light intensity light therapy administered at different times as measured by the AS

Group	Effect size (d)	95% C.I.
Morning	1.41	1.15 to 1.68
Evening	1.13	0.68 to 1.59
Morning-Evening	2.06	1.68 to 2.44

Table 7.6: Treatment effectiveness of dim light intensity light therapy administered at different times as measured by the HDRS

Group	Effect size (d)	95% C.I.
Morning	1.11	0.80 to 1.42
Morning-Evening	0.60	0.22 to 0.97

The findings of the first two analyses comparing the treatment efficacy of different timing of medium intensity phototherapy showed that morning-evening light was superior to light administered at other times of day. No significant difference in treatment effect of the morning, midday, and evening groups was observed. Superior antidepressant effect of morning light was only observed in the third analysis, when dim light condition between the morning and morning-evening light groups were compared.

The observed therapeutic effect of dim light in the present review is likely a placebo effect of insignificant clinical value. Assuming that the antidepressant effect of dim light observed in the present analysis is not a placebo effect, then the present observation would suggest that rods are likely involved in causing the antidepressant effect of dim light therapy. Following the theoretical proposition of the phase-shift hypothesis, the superiority of morning dim light to morning-evening light may suggest that low intensity light activates the rods in the retina, which has a circadian rhythm of disk-shedding peak at dawn (Reme, Wirz-Justice, & Terman, 1991). The application of morning light may phase-shift the phase response curve of the disk-shedding rhythm of the rods. Reme et al. (1991) suggested that low light intensity of about 3 lux was sufficient to phase-shift the disk-shedding rhythm of rods.

When intensity of light reached the medium level defined in the present analysis, a different pattern of findings was identified. The morning-evening light regime was consistently superior in treating the typical and atypical symptoms of SAD compared to a single pulse of light administered at any other times of the day. In other words, time of the day of phototherapy was not a significant factor for its antidepressant effect when light reached medium intensity.

The present findings are quite different from that obtained from the meta-analysis conducted by Terman et al. (1989b). Although Terman and Terman (1992) later explained that the superiority of the morning light observed in their previous study (Terman et al., 1989b) was likely due to the uncontrolled order effect in their meta-analytic review (Terman et al., 1989b), such that the success of evening light might be strongly diminished by a carryover effect of morning light, the discrepancy of their results and the present findings cannot be simply explained by the order effect, since both Terman et al.'s study (1989b) and this meta-analysis did not control for the order effect. A plausible way to explain this discrepancy is that different criteria were used to judge the clinical efficacy of phototherapy. While Terman et al. (1989b) used the strict clinical criteria for remission to conclude the relative effectiveness of phototherapy administered at different times of day, the conclusions of this meta-analysis were derived from the results of Hedges' modified ANOVA procedures. Another possible explanation was an increase in sample size in this meta-analysis.

The observed superior antidepressant effect of morning-evening phototherapy provides strong support for the photon-count hypothesis. According to the photon-count hypothesis, an increase in duration of phototherapy leads to increased photon emission and absorption and thus causes a relatively superior antidepressant effect for SAD. Based on this theoretical assumption, the observed superior antidepressant effect of the morning-evening phototherapy can be easily understood because the duration of morning-evening phototherapy is about double that of a single pulse of light administered at other times of day in the present project.

The photon-count hypothesis could explain the observed dose-response relationship in the present analysis: Increased photon absorption leads to an increase in therapeutic efficacy of phototherapy. It also somewhat supports the serotonin hypothesis of SAD, which states that light enhances the level of cortical serotonin activity.

Further evidence of the photon-count hypothesis is provided by a narrative report of one of the pioneer SAD patients in Canada, who attempted phototherapy in early 1980s. During the interview, she reported that she tended to use her light box for longer hours when there was less sunshine, and she would use her light box in the morning, afternoon, and sometimes even in the evening.

The present findings of the optimum timing of phototherapy of medium intensity argue against the phase-shift hypothesis not only because the morning-evening light regime is superior to a single pulse of light administered in the morning, midday, and evening, but also because similar treatment effect sizes are identified for the morning, midday ,and evening phototherapy. It could be argued that SAD population may be a heterogeneous one in terms of abnormally phase-advance or phase-delay of bodily circadian rhythms (Lewy & Sack, 1986). In fact, out of the 10 SAD subjects included in Rosenthal et al.'s (1990) study, six showed a phase advance and four showed a phase delay of their respective temperature rhythms. Nonetheless, while this argument could explain the similar treatment effect of morning and evening light observed in the present analysis, it could not explain why midday light is as effective as morning or evening phototherapy. Furthermore, it could not explain why the morning-evening light regime is superior to a single pulse of light administered at other times of day.

Terman (1993) advocates for the validity of the phase-shift hypothesis. He argues that nondifferential treatment efficacy of morning light and evening light is insufficient to refute the phase-shift hypothesis. Rather, it can only be refuted if light-induced phase shifts are not correlated with clinical effect. Furthermore, he suggests that artificial evening light may lose its phase-delaying capacity because the delaying limb of the PRC of SAD patients may drift toward a later nighttime hour in response to the delay in outdoor dawn illumination in winter. In this case, both morning and evening light can be therapeutic. Again, Terman's proposal can only explain the non-differential therapeutic effect of morning and evening light. It still fails to account for the anti-depressant effect of the midday light. It is also unable to explain the superiority of morning-evening light regime observed in the present analysis, because, according to Terman (1993), the administration of morning light should reset and advance the circadian rhythms of SAD patients such that the evening light could now be able to exert its phase-delaying capacity resulting in the cancellation of the therapeutic gain of the morning light.

How about the photoperiod hypothesis? The validity of the photoperiod hypothesis is also unable to be established based on the present findings. The fact that the present findings show that light administered at other times of day also produces significant treatment effect, but inferior to that of morning-evening light, refutes the photoperiod hypothesis because this hypothesis proposes that the therapeutic effect of light is to extend the photoperiod by the application of morning and evening light. This implies that a single light pulse administered at any time of day should be ineffective. As a conclusion, the present findings tend to support the photon-count hypothesis for light of medium intensity.

Other Plausible Pathophysiological Mechanisms of SAD

Many plausible etiological mechanisms are deemed to be out of the scope of the present meta-analytic review but are worth readers' attention. Apart from possible neuroendocrine abnormalities, which were briefly discussed in Chapter 2, there are other possible etiological mechanisms of SAD that deserve further investigation.

Sayer et al. (1991) reported that temperature and hours of sunshine in the month prior to admission of mania correlated significantly with the admission rate.

This observation suggests that both photons and temperature of phototherapy work together to alleviate SAD.

Oren (1991) proposes a retinal melatonin/dopamine hypothesis. According to this hypothesis, bright light works to stimulate dopamine production but suppresses melatonin secretion in the retina. The equilibrium of this photochemical reaction thus functions to bring about the antidepressant effect of light.

Volf et al. (1993) studied the hemispheric language lateralization in SAD on 37 SAD patients and observed that SAD was associated with a shift of laterality from the left to the right. This observation may suggest that those people with language functions lateralised in the right hemisphere are more vulnerable to SAD. The validity of this speculation needs to be further examined.

Recent observations in other mammals that stimuli other than light can act on circadian rhythms suggest future research on possible treatment strategies for SAD other than light. Mrosovsky (1988) reported that the exposure to a new cage or to social stimuli can shift the phase of the circadian rhythms of the experimental hamsters. Aschoff and Tokura (1986) observed that environmental temperature cycles could entrain the activity rhythms of the experimental monkeys.

Allen et al. (1993a) studied the regional asymmetries of the electroencephalogram (EEG) of four bipolar SAD patients and observed that they had greater left frontal alpha activity than normal control subjects. They then administered phototherapy and observed that while bright light significantly decreased the HDRS scores of the subjects, the greater left frontal alpha activity of the SAD subjects did not change significantly as a result of phototherapy. The findings of this study, although based on a very small sample, suggested that phototherapy did not work by altering the EEG pattern. Future exploration of the EEG activities of SAD patients is needed.

Heterogeneity of the SAD Population

The SAD population may be a heterogeneous one due to various extrinsic and intrinsic reasons. Extrinsic reasons are the variability of natural light exposure pattern (Eastman, 1990) of different individuals. Intrinsic reasons can be inter-individual differences in vulnerability. For example, Wirz-Justice and Anderson (1990) suggest that individuals differed in their sensitivity to time of day as well as to dose of light. Daimon et al. (1992) suggest that circadian disturbance in depression may be a manifestation of the weakening of the coupling processes between internal pacemakers and/or an abnormal sensitivity to environmental information, which can vary significantly among different individuals (Kerkhofs & Mendlewicz, 1985).

Another possible factor contributing to the heterogeneity of the SAD population is the possible inter-individual variation in rod and cone density. This speculation is partially substantiated by the findings that bipolar patients are more sensitive to light and could suppress melatonin when exposed to dim light (Hill, 1992). If such an inter-individual variation in photoreceptor density does exist, lux as a measurement of light intensity would not be an appropriate choice. Lux is a measurement of illumination exposure over the visible spectrum of light (Joffe et al., 1993). This illuminance measure may not accurately reflect the number of photons reaching the subject because it varies significantly with the variable spatial position of the subject resulting from head, body movements, and direction of gaze relative to the light source (Terman, 1993). Even with the use of a photo-sensor cannot control for variations in gaze, eye/eyelid movement, pupil size, and retinal adaptation state (Terman, 1993).

Photon density seems to be better able to reflect the dose of light. According to Stewart et al. (1991), photon density is a physical measure of the number of photons per unit area emitted by a light source. It should give a better estimate of the amount of photo energy reaching the retina per unit time. Of course, an even better choice would be something that would take the photon density of the light source and photoreceptor density of individual SAD subjects into account.

If the SAD population were indeed heterogeneous in nature, traditional experimental design of using treatment and control groups (Brown, 1990) may be inappropriate for studies on SAD because the lumping of individual data in a group could only serve to confound the research findings and threaten the external validity of the conclusions drawn. This may in fact account for the conflicting findings reported in the field of SAD. A single subject research methodology, though with limited external validity, may be adopted to first clarify the issue of heterogeneity of SAD population before traditional experimental design is employed.

Limitations and Delimitation

Although the validity of the present meta-analysis protected by excluding studies of low internal validity, the internal and external validity of the present findings is still limited by some of the methodological shortcomings of phototherapy studies in the field. The present meta-analysis reveals that the control of confounding variables in studies of phototherapy is generally weak.

Control for sleep, medication, and other forms of therapy, pharmacological or psychological, is indeed essential for eliminating significant confounding variables for phototherapy studies. For example, treatment in morning hours does have the risk of confounding the findings by sleep deprivation (Fleischhacker & Kasper, 1991). Also, Reme et al. (1990) reported the findings of some studies that chronic lithium treatment phase delays and dampens circadian rhythms at different levels of biological functions. This can seriously confound findings of studies on the validity of phase-shift hypothesis. Unfortunately, control for these confounding variables is not as widely practised as it ideally should be, probably due to the constraints of available resources.

Data analysis by a meta-analytic procedure can be more meaningful and beneficial if researchers begin to adopt a more unifying experimental protocol in studying phototherapy for SAD, as has been suggested by Terman et al. (1989b) in their meta-analytic review. Terman et al. (1990c) offer a good discussion on the methodological strengths and weaknesses of studies on phototherapy for SAD.

Subject compliance poses another big threat to the validity of research in this area, especially when treatment efficacy of varying doses of light or different times of light administration was ascertained. This problem is not that serious in in-patient laboratory settings but can be quite severe in out-patient settings where compliance relies solely on the self-report of the subjects. Lewy et al. (1988) pointed out the problems of natural light self-exposure/sleep-wake scheduling that may confound findings of phototherapy studies. Dawson and Campbell (1990) suggest that inter-individual differences in compliance may contribute significantly to the variability of patient response.

Although this project used a relatively large sample size, all studies except one were conducted in cities within about 35 degree latitude range (from 30 00 N to 64 50 N). Furthermore, 70% of the data were collected in the United States of America; readers should be cautious about generalising the conclusions of the present meta-analysis to other geographic locations. Also the findings of the present meta-analysis can be biased because of unequal numbers of studies included in some categories for analysis.

In the present meta-analysis, data of the selected studies are sliced to study treatment efficacy of varying phototherapy parameters. Because caution has been taken to avoid slicing the data pool too far so as not to violate the independent assumption of data sets in different analyses, potential moderator variables that vary within a narrow range in the collected studies, in particular the duration of phototherapy, distance and angle of light source from the subjects, and the light source used in the experiment, were not examined. By the same token, having been limited by the amount of data available, the present meta-analysis did not attempt to identify a true placebo nor to establish the relationship of patient's expectation and the subsequent outcome of treatment outcome of phototherapy. These are some important issues that need to be addressed in future research.

Sequence of the treatment was unable to be examined in this meta-analysis due to insufficient data available. It has been speculated that sequence effect can confuse the findings of studies on phototherapy for SAD. Terman et al. (1990b) suggest that a four-sequence design is more appropriate than the usual two condition crossover design for examining the sequence effects.

Future research should attempt this design to examine the sequence effects.

Terman et al. (1989b) introduced the strict criteria for clinical remission, i.e. HDRS score reduction of 50% or more to a level under 8, which has been widely employed ever since. In this meta-analysis, the strict criteria for clinical remission was not included in the analysis partly because data on individual subjects were not routinely reported in the studies selected for this meta-analysis and partly because strict criteria for clinical remission has not been validated yet (Doghramji et al., 1990).

Despite the above cautionary statements about the external validity of the present findings, the value of a meta-analysis in further our understanding of SAD and the mechanism of phototherapy is undeniable. This methodology allows for scientific aggregation of data collected at different times and places. The subsequent increase in sample size as a result of data pooling, help address the criticism of small sample size of phototherapy studies for SAD. It also helps resolved some of the conflicting findings and generate insight into direction of future research.

VIII. Conclusion

As suggested from the findings of the present meta-analysis, light does possess the antidepressant effect advocated by many researchers and clinicians in the field. Dose-response relation of light therapy is observed on the typical but not the atypical symptoms of SAD. Optimum timing of phototherapy remains contentious, although the present findings show that a combination of morning and evening phototherapy of medium light intensity yields the best therapeutic effect; henceforth supporting the photon-count hypothesis. Some other possible pathophysiological mechanisms of SAD, worth further exploration, are discussed in the present dissertation.

The present findings suggest that different parameters of light, e.g. light intensity, tend to have different therapeutic effects on the typical and atypical symptoms of SAD. Therefore, future studies on phototherapy for SAD should employ both the HDRS as well as the AS for better depiction of the therapeutic effect of phototherapy of different parameters. Using the Structured Interview Guide for the Hamilton Depression Rating Scale—Seasonal Affective Disorder Version (SIGH-SAD) (Williams., 1988) would be a good choice provided that both scores, one reflecting the typical symptoms of a depression and the other one representing the severity of the atypical depressive symptoms of SAD, are recorded and reported. Relying on either one of the two scores on the SIGH-SAD would open the findings to unpredictable Type I or II errors. Terman et al. (1990c) reported that the correlation between HDRS and atypical subscales of the SIGH-SAD was low and nonsignificant at base line. This strongly suggests that the two subscales are indeed measuring two independent events.

Application of light for treatment of other kinds of biological disorders due to a circadian dysfunction may offer a safe and economical treatment alternative. In particular, the efficacy of phototherapy for nonseasonal depressive patients should be further explored. So far, positive (Deltito et al., 1991; Fleischhauer, Glauser, & Hofstetter, 1988; Kripke, Risch, & Janowsky, 1983; Kripke et al., 1992; Volz et al., 1990) and negative (Kasper et al., 1990; Kerkhofs & Mendlewicz, 1985; Mackert et al., 1991; Stinson & Thompson, 1990) findings have been reported. Such a lack of consensus could be due to methodological discrepancies. Further research in this area is recommended.

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Appendix 1

PHOTOTHERAPY FOR SAD - A META-ANALYTIC REVIEW

CODING FORM

IDENTIFICATION

Study ID # :
Coder:
Authors:
Source of Data:
Name of Journal or Book:
Year of Publication:

RESEARCH DESIGN

Year Data Collection was Completed:
Country of Origin of the Study:
City of Origin of the Study:
Latitude of the City:
Setting of Study:
Study Design:
Control for Sleep:
    Sleeping Schedule:
Clear of Psychotropic Medications:
Control for Other forms of Treatment:

SAMPLING

Sample Selection Criteria:
Exclusion Criteria:
Sampling Technique:
Subjects Assignment:

SUBJECT CHARACTERISTICS

Total Sample Size:
Number of cases lost:
Number of Subjects Diagnosed as Bipolar II:
Number of Subjects Diagnosed as Bipolar I:
Number of Subjects Diagnosed as Unipolar:
Number of Males:
Number of Females:
Mean Age:
Number of Subjects in Group 1:
Number of Subjects in Group 2:
Number of Subjects in Group 3:

INDEPENDENT VARIABLE(S) (LIGHT THERAPY)

Mean Number of Days of Treatment:
Variable Manipulated:
Intensity (lux):
Spectrum of Light Used:
Distance of Light Source From Subject (cm):
No. of Treatment Sessions Per Day:
Duration of Phototherapy Per Session (hrs.)
Treatment 1: Session 1 (S11):
Session 2 (S12):
Treatment 2: Session 1 (S21):
Session 2 (S22):
Treatment 3: Session 1 (S31):
Session 2 (S32):
Timing of Light Therapy for each session: S11:
S12:
S21:
S22:
S31:
S32:
Time of commencement of therapy for each session: S11:
S12:
S21:
S22:
S31:
S32:
Time of completion of therapy for each session: S11:
S12:
S21:
S22:
S31:
S32:

DEPENDENT VARIABLE(S)

Name of Instruments:
Rating Method:
Raters Assignment:

THREATS TO INTERNAL VALIDITY

History:
Instrumentation:
Statistical Regression:
Maturation:
Attrition:
Selection:
Testing:

Summary Statistics - Effect Size Data

HDRS

Method 1

	Gp 1	Gp 2	Gp 3
Mean Pretest Score:			
Mean Posttest Score:			
Standard Deviation:			
Number of Subjects:			
Index g:			

Method 2

	Gp 1	Gp 2	Gp 3
1.t-Value:			
Degrees of Freedom:			
p-value:			
Index g:			
2.Analysis of Variance:			
Sum of Squares:			
F Statistic:			
Degrees of Freedom:			
p-value:			
Index g:			

AS

Method 1

	Gp 1	Gp 2	Gp 3
Mean Pretest Score:			
Mean Posttest Score:			
Standard Deviation:			
Number of Subjects:			
Index g:			

Method 2

	Gp 1	Gp 2	Gp 3
1.t-Value:			
Degrees of Freedom:			
p-value:			
Index g:			
2.Analysis of Variance:			
Sum of Squares:			
F Statistic:			
Degrees of Freedom:			
p-value:			
Index g:			

Appendix 2

Formulae for calculating indices g and d

1. $g = (Me - Mc)/Sp$

   where

   Me = Mean score of the experimental group
   Mc = Mean score of the control group
   Sp = Pooled standard deviation of the experimental and control groups

2. $d = g\{1 - [3/(4N - 9)\}$

   where

   N = Ne + Nc
   Ne = sample size of experimental group
   Nc = sample size of control group

Appendix 3

PHOTOTHERAPY FOR SAD - A Meta-analytic Review

DATA SUMMARY SHEET

==

INSTRUCTIONS: This questionnaire is for acquisition of data on studies of Phototherapy for Seasonal Affective Disorder (SAD). Please read the KEYS and complete the following sections.

KEYS:
* - Please Delete As Appropriate
Tx - Treatment
SD - Standard Deviation

==

UNPUBLISHED RESEARCH STUDY ON PHOTOTHERAPY

Principal Investigator(Profession):______________________

Co-Investigator(s)(Profession):__________________________
____

Data Collection commenced in:____________________________
(Month / Year)

Data Collection completed in:____________________________
(Month / Year)

Where Was the Study Conducted?___________________________
(State / Country)

Setting of the Study: * Clinic / Subject's Home
Other (please specify):
____

Has this set of data ever been published before? *
Yes / No
If yes, please specify the reference:____________________
____

Has this set of data ever been used in other studies? *
Yes / No
If yes, please specify:__________________________________
____
____

1.RESEARCH DESIGN

Experimental Design:*
A.Cross-Over Counter-Balanced Method
B. Other (Please Specify)
____

If A (Cross-over Counter-Balanced Method), how long was the recovery period? __________days.

****

Please read the following for answering questions in subsequent Sections.

Cross-Over Counter-Balanced Method

Subjects were divided into two groups and received treatments 1 and 2 at different orders. The schematic representation of this research design is as follows:

	One Group	**The Other Group**
First Trial:	Group 1 (Tx 1)	Group 2 (Tx 2)
Recovery Period:	NO INTERVENTION	
Second Trial:	Group 3 (Tx 2)	Group 4 (Tx1)

Group 1 - received Treatment 1 in the first trial
Group 2 - received Treatment 2 in the first trial
Group 3 - (subjects who were in Group 1 in the first trial) received Treatment 2 in the second trial
Group 4 - (subjects who were in Group 2 in the first trial) received treatment 1 in the second trial.

Other Method

Group 1 is the Control Group, and Groups 2, 3 and 4 are treatment groups used in your study.

2.SAMPLE OF THE STUDY

Sample Selection Criteria (Please specify):

____

____

Sampling Technique: * Random / Non-Random

If it is non-random, please specify the method used:

____

____

Total Sample Size:___________________________

Number of Groups (including control group): __________

Method of Subject Assignment: * Random / Non-Random

If it is non-random, please specify the method used:

____

____

3.SUBJECT CHARACTERISTICS

	Gp 1	Gp 2	Gp 3	Gp 4
No. of Subjects: Pre-Tx: Male Female	______ ______	______ ______	______ ______	______ ______
No. of Subjects: Post-Tx: Male Female	______ ______	______ ______	______ ______	______ ______
Mean Age (SD)	___( )	___( )	___( )	___( )
Age Range	-	-	-	-

4.PARAMETERS OF PHOTOTHERAPY (INDEPENDENT VARIABLE)

Group 1 (or Control Group)

Source of Light:___________________________________

Intensity of Light:________________________________
Spectrum of Light Used:____________________________
Distance of Light Source From Subject (cm):________

Total No. of Tx Sessions:__________________________
No. of Tx Sessions Per Day:________________________

Duration of Phototherapy Per Session (min):________

Time of the Day of Phototherapy:____________________

Other Treatment(s), If Any: ________________________

Control for Sleep: * Yes / No
If yes, please describe the procedure:

Group 2 (or Treatment Group)

Source of Light:___________________________________

Intensity of Light:________________________________
Spectrum of Light Used:____________________________
Distance of Light Source From Subject (cm):________

Total No. of Tx Sessions:__________________________
No. of Tx Sessions Per Day:________________________

Duration of Phototherapy Per Session (min):________

Time of the Day of Phototherapy:____________________

Other Treatment(s), If Any: ________________________

Control for Sleep: * Yes / No
If yes, please describe the procedure:

4.PARAMETERS OF PHOTOTHERAPY (INDEPENDENT VARIABLE)

Group 3 (or Treatment Group)

Source of Light:___________________________________

Intensity of Light:________________________________
Spectrum of Light Used:____________________________
Distance of Light Source From Subject (cm):________

Total No. of Tx Sessions:___________________________
No. of Tx Sessions Per Day:_________________________

Duration of Phototherapy Per Session (min):________

Time of the Day of Phototherapy:____________________

Other Treatment(s), If Any: _________________________
____

Control for Sleep: * Yes / No
If yes, please describe the procedure:
____
____

Group 4 (or treatment Group)

Source of Light:___________________________________

Intensity of Light:________________________________
Spectrum of Light Used:____________________________
Distance of Light Source From Subject (cm):________

Total No. of Tx Sessions:___________________________
No. of Tx Sessions Per Day:_________________________

Duration of Phototherapy Per Session (min):________

Time of the Day of Phototherapy:____________________

Other Treatment(s), If Any: _________________________
____

Control for Sleep: * Yes / No
If yes, please describe the procedure:
____
____

5.MEASUREMENT OF TREATMENT EFFECTIVENESS (DEPENDENT VARIABLES)

Number of Instrument(s) Used: ______________

Name of Instrument One: ________________________________
Reference(s):_____________________________________

Name of Instrument Two: ________________________________
Reference(s): ____________________________________

List Other Indicators of Treatment Effectiveness, If Any:
____
____

6. THREATS TO INTERNAL VALIDITY

Please rate, on the 8-point Likert scale provided below, how well the threats to internal validity of your study were controlled (circle the most appropriate number):

1 2 3 4 5 6 7 8

|-------------------|----------------------------|

No Control At All

Moderately Controlled

Fully Controlled

7.SUMMARY STATISTICS

Instrument One:

	Gp 1	Gp 2	Gp 3	Gp 4
Pre-Tx: Mean Score (SD)	___( )	___( )	___( )	___( )
Post-Tx: Mean Score (SD)	___( )	___( )	___( )	___( )
Statistical Analysis: * t-value / F-ratio Others (please specify): ________________________				
Results of Hypothesis Testing: _______ (p =				

Instrument Two:

	Gp 1	Gp 2	Gp 3	Gp 4
Pre-Tx: Mean Score (SD)	___( )	___( )	___( )	___( )
Post-Tx: Mean Score (SD)	___( )	___( )	___( )	___( )
Statistical Analysis: * t-value / F-ratio Others (please specify): ________________________				
Results of Hypothesis Testing: _______ (p =				

Other Indicator:

	Gp 1	Gp 2	Gp 3	Gp 4
Pre-Tx: Mean Score (SD)	___( )	___( )	___( )	___( )
Post-Tx: Mean Score (SD)	___( )	___( )	___( )	___( )
Statistical Analysis: * t-value / F-ratio Others (please specify): ________________________				
Results of Hypothesis Testing: _______ (p =				

ACKNOWLEDGEMENT

Do You Want Your Contribution To Be Acknowledged? *
Yes / No

If Yes, please complete the following:

Name(s):____
____
____
____

Name of Institute:________________________________

Address:____
____

Telephone No.:___________________________________

Fax No.:____

Thank You For Your Participation. Please send this questionnaire to Tatia M. C. Lee on or before 31st July, 1994 by mail or fax.

Address: 1-135 Education North
Clinical Services
University of Alberta
Edmonton, Alberta
Canada T6G 2G5

Fax: (403) 437-5135

Appendix 4

Published studies

Allen et al. (1993). Regional electronencephalographic asymmetries in bipolar seasonal affective disorder before and after exposure to bright light. Biological Psychiatry, 33, 642-646.

Avery et al. (1991). Morning or evening bright light treatment of winter depression? The significance of hypersomnia. Biological Psychiatry, 29, 117-126.

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Yerevanian, B. I., Anderson, J. L., Grota, L. J., & Bray, M. (1986). Effects of bright incandescent light on seasonal and nonseasonal major depressive disorder. *Psychiatry Research*, 18, 355-364.

****

Unpublished studies

Ravaris, C. L. (p.c.)

Anonymous (p.c.)

Blashko, C., Janzen, H., Paterson, J. (p.c.)

Appendix 5

Studies	N	W	Effect Size	
			HDRS	AS
No Light				
McGrath et al. (1990)	13	-	0.59	2.96
Eastman et al. (1992)	32	-	0.89	0.81
Terman et al. (1989)	26	-	0.12	0.62
Morning Dim				
Rosenthal et al. (1987)	11	1	-0.22	-
Lam et al. (1991)	11	1	0.82	0.63
Joffe et al. (1993)	33	2	1.86	1.33
Joffe et al. (1993)	38	2	1.70	1.88
Avery et al. (1993)	9	4	1.24	1.55
Avery et al. (1993)	13	4	2.52	2.38
Magnusson et al. (1991)	5	3	0.31	-
Blashko et al. (p.c.)	36	1	0.74	0.86
Morning Medium				
Avery et al. (1991)	19	1	0.58	-
Rosenthal et al. (1987)	11	1	0.00	-
Avery et al. (1992)	7	4	1.65	1.40
Avery et al. (1992)	7	4	2.93	2.73
Takahashi et al. (1991)	17	1	1.71	-
Oren et al. (1991)	14	3	0.86	-
Oren et al. (1991)	14	3	1.67	-
Bielski et al. (1992)	11	1	2.92	-
Bielski et al. (1992)	11	4	2.51	-
Lam et al. (1991)	11	1	2.05	1.04
Lam et al. (1994)	11	2	0.71	1.52
Wirz-Justice et al.(1987)	23	1	1.30	-
Wirz-Justice et al.(1987)	25	1	1.47	-
Meesters et al. (1993)	16	1	1.61	1.20
Joffe et al. (1993)	34	2	2.07	1.78
Yerevanian et al.(1986)	6	4	2.78	-
Hellekson et al. (1986)	14*	1	2.82	-
Lam et al. (1992)	16	1	2.10	1.40
Lam et al. (1992)	17	2	2.00	1.60
Sack et al. (1990)	9	1	2.19	0.83
Lewy et al. (1987)	8	1	1.5	-
Jacobsen et al. (1987)	16	1	1.01	-
Avery et al. (1990)	7	1	2.86	-
Stewart et al. (1991)	12	4	0.67	1.13
Volf et al. (1993)	13	1	1.52	-

Studies	N	W	Effect Size	
			HRSD	AS
Morning Strong				
Eastman et al. (1992)	32	2	0.94	1.14
Magnusson et al. (1991)	5	1	4.28	-
Blehar et al. (1990)	24	2	2.96	-
Anonymous (p.c.)	11	1	2.91	2.18
Blashko et al.(p.c.)	36	1	1.60	1.28
Midday				
Jacobsen et al. (1987)	16	1	1.06	-
Magnusson et al. (1991)	5	3	1.52	-
Magnusson et al. (1991)	5	1	2.44	-
Volf et al. (1993)	15	1	1.37	-
Evening Dim				
James et al. (1985)	9	1	0.63	-
Evening Medium				
Avery et al. (1991)	19	1	1.31	-
McGrath et al. (1990)	13	1	2.92	1.98
Rosenthal et al. (1985)	9	1	1.53	-
Meesters et al. (1993)	11	1	2.16	1.02
Yerevanian et al. (1986)	5	4	1.23	-
Hellekson et al. (1986)	13*	1	2.86	-
Sack et al. (1990)	9	1	1.03	0.68
James et al. (1985)	9	1	1.33	-
Lewy et al. (1987)	8	1	0.02	-
Avery et al. (1990)	7	1	0.82	-
Doghramji et al. (1990)	6	1	2.20	0.68
Doghramji et al. (1990)	6	1	2.40	1.75
McIntyre et al. (1989)	6	1	1.08	-
Wehr et al. (1987)	10	1	1.93	-
Wehr et al. (1987)	10	1	0.38	-
Morning-Evening Dim				
Rosenthal et al. (1985)	28*	1	0.60	-
Wirz-Justice et al.(1986)	4	4	1.43	-
Rosenthal et al. (1984)	9	4	0.32	-
Isaacs et al. (1988)	11	1	0.76	-
Allen et al. (1993)	4	1	0.56	-

Studies	N	W	Effect Size	
			HRSD	AS
Morning-Evening Medium				
Rosenthal et al. (1985)	28*	1	2.00	-
Wehr et al. (1991)	7	1	1.75	1.71
Wehr et al. (1991)	7	1	1.55	1.50
Wirz-Justice et al.(1986)	4	1	2.69	-
Rosenthal et al. (1984)	20*	1	2.35	-
Hellekson et al. (1986)	6	1	3.22	-
Isaacs et al. (1988)	11	1	0.69	-
Isaacs et al. (1988)	11	1	1.37	-
Stewart et al. (1990)	25	1	2.87	2.56
Lewy et al. (1987)	8	1	0.96	-
Terman et al. (1989)	21	1	1.63	1.62
Terman et al. (1989)	25	1	2.84	2.61
Allen et al. (1993)	4	1	0.66	-

Keys

* Sample size modified after weighing

W Wavelength of light used
  1 - Full spectrum light with the UV wavelengths
  2 - Cool-white or full spectrum light without the UV wavelengths
  3 - Red Wavelengths
  4 - Blue/Green/Yellow Wavelengths

Appendix 6

Area of study: Spectral properties of phototherapy

Hypothesis: A full spectrum light is more effective in treating SAD than any selected spectrum of light.

To verify this hypothesis, studies of median light intensity were selected for further analysis. They were then divided into four groups of different wavelengths:

Group 1: Full-spectrum light with the UV component
Group 2: Cool-white or full-spectrum light without the UV component
Group 3: Red wavelengths
Group 4: Green/Blue/Yellow wavelengths.

Treatment efficacy among these groups were compared.

Two analyses were conducted on the available data so as to verify this hypothesis. The first one compared the treatment effect size, measured by the HDRS, of groups 1 to 4. The second analysis compared the results of the AS obtained on groups 1, 2, and 4.

Results

Treatment effect sizes, measured by the HDRS, of the four treatment groups using different spectra of light are presented as follows:

Group 1: Full spectrum light with the UV component (range of effect sizes = 0.00 to 3.22)

Group 2: Cool White or Full-spectrum light without the UV component (range of effect sizes = 0.71 to 2.96)

Group 3: Red wavelengths (range of effect sizes = 0.31 to 1.52)

Group 4: Green/yellow wavelengths (range of effect sizes = 0.32 to 2.93)

Group 1 was further divided into three subgroups according to the timing of phototherapy administration. The results are presented in Table A6.1

Table A6.1: Effect of light of different wavelengths for treatment of SAD measured by the HDRS

Variable	K	N	Mean weighted d	95%C.I.for d	Q
Group 1					
morning	15	227	1.47	1.26 to 1.69	19.19*
	14	205	**1.71**	**1.48 to 1.94**	20.53
evening	15	145	1.28	1.02 to 1.54	33.35*
	13	128	1.49	1.18 to 1.74	22.99*
	12	118	**1.59**	**1.30 to 1.89**	14.53
morning-evening	13	176	1.84	1.58 to 2.09	31.10*
	11	161	2.01	1.74 to 2.28	19.18*
	10	153	**2.09**	**1.81 to 2.38**	14.38
Group 2	7	189	1.65	1.41 to 1.89	24.35*
	6	165	1.54	1.29 to 1.79	14.39*
	5	146	**1.98**	**1.70 to 2.26**	6.58
Group 3	3	24	**0.79**	**0.20 to 1.39**	1.35
Group 4	11	96	1.41	1.09 to 1.74	21.99*
	10	88	**1.59**	**1.24 to 1.93**	15.20

Group 3, red wavelengths, appeared to produce the smallest effect size for treating the typical symptoms of SAD. The different treatment efficacy of Groups 1, 2, and 4 was difficult to delineate by just comparing their respective estimated effects sizes because of the degree of overlap of their respective C.I. Analysis of variance procedures following a fixed effect model, suggested by Hedges (1994, p.285-299), was conducted to further verify this hypothesis.

The findings of the modified ANOVA showed a statistically significant difference in the treatment effect sizes among the four groups. The findings are presented in Tables A6.2 to A6.4 below.

Table A6.2: Results of the contrast of ANOVA (Morning light subgroup)

Group Contrast				Chi-square value (df=1)
1	2	3	4	
X	X			1.56
X		X		8.05*
X			X	0.13
	X	X		11.85*
	X		X	1.83
		X	X	5.74*

* denotes significant findings, $p < 0.05$

Table A6.3: Results of the contrast of ANOVA (Evening light subgroup)

Group Contrast				Chi-square value (df=1)
1	2	3	4	
X	X			2.37
X		X		5.97*
X			X	0.01
	X	X		11.85*
	X		X	1.83
		X	X	5.74*

* denotes significant findings, $p < 0.05$

Table A6.4: Results of the contrast of ANOVA (Morning-Evening light subgroup)

Group Contrast				Chi-square value (df=1)
1	2	3	4	
X	X			0.51
X		X		15.00*
X			X	3.93*
	X	X		11.85*
	X		X	1.83
		X	X	5.74*

* denotes significant findings, $p < 0.05$

The findings showed that red light was less effective in controlling the typical depressive symptoms of SAD than other spectra of light, Groups 1, 2, and 4. Apart from the morning-evening light subgroup of Group 1, which produced a significantly larger effect size than Group 4, no statistically significant difference in treatment efficacy among Groups 1, 2, and 4 was identified.

The second analysis was conducted on the results of the AS obtained for Groups 1 (range of effect sizes = 0.68 to 2.56), 2 (range of effect sizes = 1.14 to 1.88), and 4 (range of effect sizes = 1.13 to 2.73). The results are presented in Table A6.5.

Table A6.5: Effect of light of different wavelengths for treatment of SAD measured by the AS

Variable	K	N	Mean weighted d	95%C.I.for d	Q
Group 1	16 15	230 205	1.24 **1.14**	1.04 to 1.44 **0.93 to 1.35**	25.32* 13.16
Group 2	7	178	**1.51**	**1.27 to 1.74**	5.03
Group 4	5	48	**1.61**	**1.15 to 2.08**	5.36

As noted in Table A6.5, wavelengths used in Group 4 appeared to be more effective than those used in Group 2 and then Group 1 for alleviating the atypical symptoms of SAD, but the degree of overlap of the C.I. of their respective estimated effect sizes suggested that their relationships may not be as simple as depicted above. Therefore, analysis of variance procedures following a fixed effect model, suggested by Hedges (1994, p.285-299), was conducted to further verify this hypothesis. The findings of the modified ANOVA showed a statistically difference in the weighted mean effect sizes among the three groups (Chi-square value = 7.21, df=1, $p<0.05$). The effect size produced by Group 1 was significantly smaller than that of Groups 2 (Chi-square value = 4.61, df=1, $p<0.05$) and 4 (Chi-square value = 4.39, df = 1, $p<0.05$). There was no statistically significant difference in the treatment effect size between Groups 2 and 4 (Chi-square value = 0.79, df=1, $p>0.05$).

Discussion

In the present meta-analysis, spectra of light used in phototherapy studies are categorised into four different groups, according to their wavelengths in the visible spectrum of light (Matlin & Foley, 1992). Effectiveness of individual wavelength is not ascertained due to insufficient data. The first group is full-spectrum light with the UV component, the second group is cool white or full-spectrum light without the UV component, the third group is light of red wavelengths, and the fourth group is light of blue, green, or yellow wavelengths.

Optimum wavelengths of light for SAD was examined in two separate analyses. The first analysis was to compare treatment efficacy of Groups 1 to 4 measured by the HDRS. The second analysis was to examine the different treatment effect of Groups 1, 2, and 4 measured by the AS. The findings are summarised in Tables A6.6 and A6.7.

Table A6.6: Treatment effectiveness of different spectra of light measured by the HDRS

Group	Effect size (d)	95% C.I.
1 morning	1.71	1.48 to 1.94
Evening	1.59	1.30 to 1.89
Morning-Evening	2.09	1.81 to 2.38
2	1.98	1.70 to 2.26
3	0.79	0.20 to 1.39
4	1.59	1.24 to 1.93

Table A6.7: Treatment effectiveness of different spectra of light measured by the AS

Group	Effect size (d)	95% C.I.
1	1.14	0.93 to 1.35
2	1.51	1.27 to 1.74
4	1.61	1.15 to 2.08

The findings of the first analysis showed that red wavelengths were significantly ineffective in treating the typical depressive symptoms of SAD measured by the HDRS. No difference in the treatment efficacy of other groups was identified. In the second analysis, the results showed that light without the UV component, as well as the blue/green/yellow wavelengths, was more effective in alleviating the atypical symptoms of SAD measured by the AS.

The present findings suggest that red wavelengths are relatively ineffective for SAD; whereas light of short to medium wavelengths, i.e. blue and green wavelengths of the spectrum, is necessary for the antidepressant effect of phototherapy. Nonetheless, these findings may have been significantly confounded by the fact that phototherapy studies employing red wavelengths used dim intensity light (</= 600 lux); whereas light of other spectra was medium to strong intensity. The observed insignificant anti-depressant effect of red light may be compromised by the dim intensity used in respective phototherapy studies.

Assuming that light intensity was not a significant confounding factor, the present observation suggests that an insufficient number of functioning M and S cones may be one of the predisposing/precipitating factors for SAD. This speculation seems to be consistent with Lam et al.'s (1991b) proposal that subtle retinal abnormalities at the level of the photoreceptor/retinal pigment epithelium complex, consistent with sub-sensitivity to light, may link with the etiology of SAD.

With respect to the UV wavelengths, the present findings suggest they are not necessary for the antidepressant effect for SAD, both for alleviating the typical or atypical symptoms. Due to the potentially harmful effect of the UV wavelengths, they should not be used in phototherapy for SAD.

Conclusion

The antidepressant effect of light does not seem to be the same for different spectra of light. Light of short to medium wavelengths (blue/green/yellow) seems to be essential for the therapeutic effect of light for SAD. Red wavelengths are relatively ineffective, but low intensity of red light used in phototherapy studies can be a very significant confounding factor.

It is postulated that SAD may be predisposed/precipitated by the inefficiency of the S and M cones in the retina. Furthermore, ultraviolet (UV) waves does not seem to be essential for SAD symptom alleviation by artificial light. Therefore, these potentially harmful UV waves should be blocked in any clinical application of phototherapy for SAD.